Negative and Positive Priming in Poor and Good Readers: An ERP Study

by

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Abstract

This thesis addresses three issues with respect to information processing in the negative priming paradigm. The first concerns whether depth of processing can be shown to affect response time (RT) and event-related potential (ERP) components taken to Probe stimuli. The second issue concerns whether the temporal locus of positive and negative priming can be differentiated using ERPs latencies. The third issue addresses whether adult poor readers differ from adult good readers in the way in which they display positive and negative priming effects across tasks of differing depth of processing. First-year university students were tested on several reading and attentional measures and three priming tasks. Results indicate that priming effects, ERP latencies, and RT latencies vary with depth of processing. ERP latencies indicate that negative priming effects occur later than positive priming effects. Contrary to predictions, poor and good readers do not differ in negative priming or early positive priming effects. Poor and good readers do differ in positive priming effects, but not as predicted. These results are discussed in terms of popular models of attention and the negative priming model. Differences in performance between poor and good readers are discussed in terms of attentional theory, the negative priming model and current reading theory.

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Introduction

Posner (1985) and Tipper (Tipper, Bourque, Anderson, & Brehaut, J. C. 1989; Houghton & Tipper, 1994) propose that facilitory attentional effects occur both early and late in processing and that inhibitory attentional effects occur only later in processing. Previous studies have not examined the time-course of facilitory and inhibitory effects within the trials where they occur because the paradigms are all based solely on the response time (RT) occurring at the end of the trial. This thesis employed event-related potentials (ERPs) which reflect ongoing processing and allow examination of the time-course of facilitory and inhibitory effects.

We examined facilitory and inhibitory effects with respect to reading ability. Whereas poor readers are deficient compared to good readers on standard phonological tasks, they do disproportionately well on orthographic tasks, perhaps due to an inability to inhibit orthographic or visual stimulus information. This was tested by comparing negative and positive priming conditions in poor versus good readers.

Perceptual and Attentional Processes Occurring Prior to Motor Output

Posner and Snyder (1975) hypothesize a two-process model of stimulus information processing occurring prior to motor output. See Figure 1 for a schematic diagram of these two processes. In this model it is proposed that information is initially processed in parallel, non-competing pathways not requiring attentional resources. Presentation of a stimulus that was previously presented is thought to lead to a speedup at this earlier stage of processing, whether this stimulus is congruent or not with the response requirements of the task. Following this initial processing comes a second stage of processing requiring controlled attention. Attention, in this instance, involves processing that serves to isolate a perceptual representation of a stimulus and make a connection between it and a motor output system. One consequence of the selection of a perceptual representation and connection with a motor output system is the exclusion of other perceptual representations from access to attentional processes. Because of this exclusion the second stage of processing is described as having a limited capacity. If the stimulus on a given trial is the same as or related to (in a task-relevant way) the previous trial's stimulus, facilitation can occur at both the first and second stages. If a given trial's stimulus was previously ignored or conflicts in a task-relevant way with the previous trial's stimulus, a slowdown (inhibition) at the second stage can occur relative to a neutral stimulus condition. The most common measure of facilitation and inhibition is response time.

Friedrich, Henik, and Tzelbov (1991) showed that interference effects do not occur if stimuli do not conflict in a task-relevant way. Using a naming task these researchers found that attention to semantic properties of words led to either inhibitory, facilitory, or neutral effects on response time to a trial's probe stimulus depending on whether the semantic property of the previous trial's stimulus conflicted, was in agreement, or was neutral with respect to that trial. This semantic priming effect was eliminated when task demands were changed from attention to semantic properties of words to attention to a non-semantic property (i.e. using a letter-searching task).

The Stroop task is an example of a test with consistent results that can be interpreted in terms of the two-stage theory (Posner, 1985). Part of the Stroop task involves asking a person to name the colour of the ink with which a word representing a colour (e.g. **RED**) is printed. When the ink colour conflicts with a word's written identity a person will often read the word rather than name the colour. It is thought that both the word's name identity and ink-colour identity are elicited automatically and in parallel. However, only one response can be generated. The name identity of the word is thought to be produced more quickly than the ink-colour identity and can therefore potentially end up becoming the response (incorrect in this instance).

Although the Stroop effect can be interpreted in terms of this two-process theory, it does not directly test the hypothesis that there is an earlier, parallel stage of processing followed by a later, limited-capacity stage requiring attention. Actual separation of the first and second stages of processing through experimental manipulation is the subject of much research and theory. Several methods have been employed to investigate these two stages.

Locating whether processing that is necessary for facilitory or inhibitory effects in a later trial occurs earlier and later can be done by varying the interval between the presentation of the first stimulus and the second stimulus in such a way that at the smallest interval(s) there is not enough time for the limited-capacity processing which is necessary for inhibitory effects to occur in a later trial to be carried out on the first stimulus. Under this condition one would expect to see facilitory effects only. As the interval between the two stimuli increases, limited-capacity processing necessary for later inhibitory effects should emerge and grow stronger to a maximal level that varies with stimuli used and task demands.

Neely (1977) conducted such a study, using intervals between pairs of trials of 250, 400, 700, and 2000 ms. The first members of these pairs of trials will be called Primes and the second members Probes. In his study, Neely used Prime stimuli which could semantically conflict (e.g. **BIRD-arm**), not conflict (e.g. **BIRD-robin**), or be neutral (e.g. **XXX-robin**) with respect to Probe stimuli. Participants were required to make a word/non-word judgement about Probe stimuli. Neely predicted and found that Probe stimuli preceded by conflicting prime stimuli did not take longer to respond to than Probe stimuli preceded by neutral stimuli when the Prime-Probe interval was 250 ms but did take longer to respond to when the prime-probe interval was 400, 700, and 2000 ms. In fact, the interference effect (increased response latency) increased from 400 to 700 ms but did not increase from 700 to 2000 ms. Facilitation effects (decreased latency for Probe stimuli preceded by semantically related Primes compared to Probe stimuli preceded by semantically neutral stimuli) were present at 250 ms Prime-Probe interval and did not change significantly for the 400 ms intertrial interval or for any other interval. Neely interpreted these results as supporting Posner's theory of earlier, parallel processing followed by a later, limited-capacity serial processing stage that could result in inhibitory effects given the proper prime-probe conflict.

Posner and Snyder (1975) also performed a study that manipulated the interval between Prime and Probe stimuli (50, 150, 300, and 500 ms). In addition, they manipulated the amount of attention paid to Prime stimuli by manipulating the probability (0.8 or 0.2) that the prime stimuli would contain information useful in the following probe task. As with the study by Neely (1977), facilitation effects were found but interference effects were not with short Prime-Probe intervals (50 and 150 ms). Inhibitory effects were found at Prime-Probe intervals of 300 and 500 ms but only when Prime stimuli were likely to provide information useful in the following Probe task (the 0.8 condition). Thus, it seems that Prime stimuli need a certain amount of time and sufficient attention for inhibitory effects to occur.

Another method of separating the two stages of processing is to use a task expected to be associated with inhibitory effects and use a measure sensitive to processing that spans both the earlier parallel stage and the later limited-capacity stage. Event-related potentials (ERPs) are a good measure to use for this purpose since they give very good temporal and intensity measurements of electrical activity associated with brain events occurring from earlier than 100 ms following stimulus onset to response time. Posner, Klein, Summers, and Buggie (1973) used ERPs in this way by overlaying the tracings of averaged ERPs in conditions where participants were asked to count the number of occurrences of visually presented letter pairs whose items were presented sequentially and that could either be the same or different. In one condition, participants were instructed to count the number of letter pairs that were the same (Count Same condition). A second condition required participants to count the number of letter pairs that were different (Count Different condition). Posner et al. (1973) did not analyze the ERPs in terms of components (such as N1, P2, N2, and P3) but instead hypothesized that the ERP to matching letter pairs would diverge from the ERPs to mismatching letter pairs. Matching letter pairs were expected to lead to facilitation effects only while mismatching pairs were expected to lead to interference effects. If interference effects occur later than facilitory effects one would expect that the ERPs to the Count Same condition and the Count Different condition to diverge earlier for the matching stimuli than for the mismatching stimuli.

When comparing Count Same and Count Different ERPs for letter matches, Posner et al. (1973) found that the ERP for the Count Same condition became significantly more positive than the ERP for the Count Different condition at 200 ms. For mismatch stimuli the ERP for the Count Different condition became significantly more positive than the ERP for the Count Same condition at around 300 ms. Thus, this divergence latency was, in this study, at the point of the N2-P3 complex. Posner interprets this finding as indicating that ERPs can be used to measure the time course of cognitive processing and that a mismatch between two input signals can lead to a delay in processing (Posner, 1985).

Several researchers (for example, see Hougton & Tipper, 1994; Neumann & DeSchepper, 1991; Gernsbacher & Faust, 1991) believe that selection of only one perceptual representation for motor output (and thus a limited capacity) is achieved through the active enhancement (excitation) of one perceptual representation and the dampening, or inhibition of competing representations. In this model, a perceptual representation is defined as a group of neurons, each of which responds maximally to a property of a stimulus such as colour. These neurons are thought to be connected such that their simultaneous firing and interconnectedness lead to an increase in their firing. When a perceptual representation is sufficiently foregrounded relative to competing stimuli it is able to be selected for binding with an output mechanism. Inhibitory effects, according to this model, are caused when a backgrounded perceptual representation becomes a target stimulus in a later trial. In this case more time is needed for the backgrounded perceptual representation to become foregrounded since backgrounding involved a reduction its activity level. Thus, perceptual representations are selected based on their level of activity relative to the activity level of competing perceptual representations. The availability of additional information about a stimulus, (such as its name, or its phonological structure) should serve to better define its perceptual representation. A perceptual representation that is more effectively defined should also be more effectively enhanced or inhibited.

A note on investigations of inhibitory effects. An assumption of studies of inhibitory effects is that conditions necessary for both positive and negative priming are established in the

Prime trial and that the effects of these conditions (positive or negative priming effects) are seen in the Probe trial. By manipulating the Prime-Probe interval, studies like Neely's (1977) do not directly measure inhibitory process in the Probe trial but rather measure changes in the Probe trial due to manipulation of the process antecedent to inhibitory effects. Thus, the finding that with short Prime-Probe intervals (< 300 ms) only facilitory effects occur suggests that processing necessary for Probe-related positive priming effects occurs earlier than the processing necessary for inhibitory effects. It is inappropriate to conclude the time-course of facilitory and inhibitory effects in the Probe trial from this manipulation. In studies like Neely's (1977) and in Houghton and Tipper's (1994) paradigm, response time indicates the degree of response speedup or slowdown in the Probe trial resulting from processing occurring in the Prime trial.

One focus of this study will be to investigate the time-course of facilitory effects in the Probe trials using ERP latency which provides information about on-going processing not available through RT latency in the traditional priming paradigm. The use of RT paradigms permits very indirect inferences about the time course of facilitory and inhibitory events. ERPs more directly monitor such events in real time by monitoring their post-stimulus electrophysiological correlates with millisecond resolution. This study will investigate the time-course of facilitory and inhibitory effects in Probe trials using the negative priming paradigm.

The Negative Priming Paradigm

In the negative priming paradigm (Houghton & Tipper, 1994), it is proposed that excitation and inhibition are the mechanisms by which attention operates to select one stimulus for further action. In this paradigm, a Prime trial occurs in which a stimulus to be responded to (an attended stimulus) and another stimulus which is to be ignored (an ignored stimulus) are presented simultaneously. Following the Prime trial comes a Probe trial in which another stimulus is present that is to be responded to along with a stimulus to be ignored. In both the Prime and Probe trials, the ignored and attended stimuli are in close proximity or are overlapping. The ignored stimulus in the Probe trial is always novel while the attended stimulus in the Probe trial can be (a) the same stimulus as the Prime attended stimulus, (b) the same stimulus as the

Prime ignored stimulus, or (c) a novel stimulus. When the attended stimulus in the Probe trial was also the Prime attended stimulus, response time is reduced compared to response time to a novel stimulus. When the attended stimulus in the Probe trial was the ignored stimulus in the Prime trial, response time is increased compared to response time to a novel stimulus. The reduced response time is referred to as a facilitory effect and the increased response time is referred to as an inhibitory effect. In addition to their stress on the action of both excitation and inhibition in attentional processes, Houghton and Tipper (1994) stress that stimuli, in both ignored and attended conditions, are processed to a perceptual-representational level. This means that even though a stimulus is to be ignored, it is processed by the early parallel system up to a point at which the level of excitation of neurons making up its perceptual representation is significantly higher than that of neurons not involved in a perceptual representation.

When stimuli are familiar (e.g. letters are more familiar than novel symbols) or are processed more thoroughly (e.g. when printed words are to be responded to according to their phonological rather than their orthographic characteristics alone), perceptual representations should be formed that are more well-defined than when stimuli are not familiar or are processed less thoroughly. As was previously stated, perceptual representations that are more well-defined should be both more effectively enhanced and inhibited than less well-defined perceptual representation.

ERPs as Measures of On-Going Processing.

So far, no published studies have reported direct evidence for the chronological separation of negative and positive priming effects in processes occurring prior to response time in the Probe trial. All published studies so far have relied on differences in response time between neutral and previously attended or previously ignored stimuli to find facilitory and inhibitory effects as compared to ERP measures which give information about on-going processing.

ERP components are thought to be one result of post-synaptic potentials occurring in large numbers of cortical pyramidal cells that are arranged more or less in parallel (Martin, 1991). ERP component latency is interpreted to be a measure of the time it takes for neurological processing related to that component to occur.

The latency of the N1 (80 to 150 ms post stimulus onset) and P2 (150 to 250 ms post stimulus onset) components is thought to be related to processing involved in stimulus detection and elaboration. These components are often referred to as “exogenous”, meaning that their latency is highly related to stimulus factors, i.e. not related to the cognitive set of the participant. Increasing the difficulty of stimulus detection and discrimination of a stimulus is associated with an increase in the latency of the N1 and possibly the P2 components.

Later components such as the N2 (200 to 400 ms post stimulus onset) and P3 (300 to 700 ms post stimulus onset) are often referred to as “endogenous”, since they are strongly related to factors such as the relevance of a stimulus to task demands and the frequency of a stimulus relative to other stimuli. The latency of these components is thought to vary with the time to categorize a stimulus (N2) and evaluate it in terms of task demands and other stimuli (P3) (Ritter, Simson, Vaughan, & Friedman, 1979). Thus, it is not until the N2 and P3 components at least that the ERP is thought to reflect the conceptual context, or the object level (Houghton and Tipper, 1994) of the processing.

Reading and its Attentional Aspects

Many researchers have found evidence that poor readers may have particular difficulty in accessing the phonological code of a graphemic stimulus such as a letter or a word. Brady and Rapala (1989) found that poor reading children made significantly more errors than good reading children in a word repetition task under multisyllabic and pseudoword stimulus conditions but not under a monosyllabic stimulus condition. They did not differ under any stimulus condition on response time. Brady and Rapala interpreted this finding as consistent with the hypothesis that part of poor readers' reading difficulty may involve difficulties in phonological encoding of verbal stimuli. Das, Mishra, and Kirby (1994) also found evidence of differences in performance between poor and good readers on tasks that required rapid phonological coding of verbal stimuli and pronounceable non-word stimuli. These tasks were able to classify their participants into poor and good reading groups with an up to 80% agreement with the original classification. The performance among the poor reading group was not found to vary with IQ, although all poor readers were within normal IQ limits. These researchers also concluded that an important aspect of poor readers' reading difficulty may be that they have problems with phonological coding.

Wolf (1986), in a three-year longitudinal study found results similar to Das, Mishra and Kirby (1994), namely that rapid naming tasks were able to discriminate between poor and good readers in their group across the three years of the study (participants started the study in kindergarten). Performance on these tasks on the first year of the study was able to predict later reading performance. Performance on reading comprehension tasks and discrete word reading tasks was only able to distinguish between poor and good readers in the first year of the study. It is suggested that the rapid naming tasks were so successful in discriminating between poor and good readers because these tasks challenged the limits of processing systems related to reading in the poor readers. Wolf interpreted these findings as consistent with theories that poor readers may have difficulties in automatically processing aspects of visual stimuli needed in the reading process.

Hunt and Badawi (1985) asked poor reading and good reading children to read word triads, repeat a series of two digit numbers during an interval period, then recall the previously read words. The words in each triad could be semantically, phonetically or visually similar. Poor readers showed similar patterns of interference to good readers when the triads were semantically and phonetically similar. However, the performance of poor readers was severely reduced compared to that of good readers when the triads were visually similar. Hunt and Badawi (1985) concluded that poor readers' reading difficulty should be discussed in terms of problems in the translation of visual information into a phonetic form.

Siegel, Share, and Geva (1995) compared the performance of poor reading children and younger, reading-level matched good readers on a pseudoword reading task and a task of orthographic awareness. For both poor and good reading groups, participants were found who ranged in reading level from grade one to grade eight. The pseudo-word task consisted of a list of pronounceable pseudo-words with a range of difficulty. The orthographic awareness tasks consisted of 17 pairs of pronounceable nonwords. One member of each pair was orthographically legal while the other contained a bigram that never occurred in the English language. Participants were required to select the pseudoword that “looked like a word”. Across reading levels, poor readers made fewer errors than good readers on the orthographic awareness task and more errors than good readers on the pseudoword reading task. Siegel, Share, and Geva (1995) conclude that relative to good readers, poor readers are skilled at using the orthographical information but poor at using phonological information contained in written language.

The work of reading researchers such as Wolf (1986) and Hunt and Badawi (1985) indicates that poor readers may have particular difficulty in tasks which require selective attention and responses to stimuli based on their phonological characteristics. However, Siegel, Share, and Geva (1995) showed that relative to good readers, poor readers may be unimpaired on tasks requiring selective attention and responses to visual stimuli based on their orthographic characteristics. It may be that poor readers have difficulty in transferring attention from visually-based to phonological aspects of visual stimuli. Thus, poor readers may be “captured” by visually-based aspects of visual stimuli such as orthographics.

The nature of these perceptual processing and attentional difficulties has not, however, been explored in terms of theories of attention such as Posner's and of the mechanisms of attention such as Houghton and Tipper's (1994). Under the negative priming paradigm, important measures of selective attentional processes are positive and negative priming effects. An important factor influencing negative and positive priming effects is thought to be the effectiveness of processes related to stimulus selection. Poor readers should be equally effective at selecting stimuli in tasks requiring responses based on visual aspects of stimuli and should show at least as much negative and positive priming as good readers to such stimuli. When asked to make responses based on phonological aspects of stimuli, poor readers should show a decrease in both negative and positive priming effects because of difficulty with phonological processing.

Possible subtypes of poor readers. Some researchers, such as Malatesha and Dougan (1982) and Aaron (1982) suggest that the types of problems displayed by dyslexics can be grouped into more than one category. Aaron (1982) (and developmental theorists) suggest that normal reading involves the use of both whole-word/gestalt analysis and analysis of words which is based on their spelling-sound (grapheme-phoneme) correspondence. Whole-word analysis is thought to rely on the simultaneous (parallel) gestalt-like processing of salient elements within a word as well as sequential processing of important elements within a word. Simultaneous processing is thought to be relatively insensitive to the ordering of elements such as letters and to the spelling-sound correspondence of letters and word elements. Spelling-sound reading is thought to involve sequential processing of the elements being examined as well as an understanding of the spelling-sound correspondence of word elements. Sequential processing is thought to take longer than simultaneous processing and is thought to be relatively insensitive to the visual aspects of a stimulus. Aaron believes that both processing methods are used in normal reading, and also that these processes are independent. Aaron suggests that developmental dyslexia in many people may involve poor skills in one of these processing strategies, resulting in reading that relies on an unbalanced and inefficient reliance on the other strategy. Someone who is poor at sequential processing would compensate by using the simultaneous whole-word method. Since sequential analysis of elements within a word could not be called upon when, for example, a novel word was encountered, or when verification of a word's hypothesized identity was necessary (e.g. when there were more than one possible word with a similar spelling), reading accuracy, speed, and comprehension would suffer. On the other hand, a reader who is poor at simultaneous processing would attempt to read words according to their spelling-sound correspondence. This slows reading down to such an extent that the reader suffers serious comprehension difficulty.

Malatesha and Dougan (1982) suggest that since the reading problems of dyslexics may be due to different, sometimes complementary processing difficulties, failure to make distinctions between different types of reading difficulties across individuals could “account for the bland outcome of the numerous research studies which often fail to come up with any consistent differences between normal and disabled readers".

General Description of the Present Study

The present study was conducted to investigate the time course of negative and positive priming effects using ERP and response time measures. The use of ERPs was expected to allow us to examine ongoing information processing during positive and negative priming conditions, giving us a direct measure of priming effects.

In addition, measures of reading ability were taken in order to assess the possibility that variations in reading ability are related to variations in the way in which perceptual and attentional resources are deployed. It was anticipated that ERP and response times for negative and positive priming stimuli would reflect differences related to reading skill.

The present study used the negative priming paradigm in three task conditions expected to differ in familiarity and in depth of processing requirements. Two tasks involved a geometric decision, one about non-letter figures and the other about letters. The other task involved a phonological decision. In the first task (Figures task) participants were required to make a judgement about whether the attended prime and probe stimulus each contained an enclosed space (e.g. ∝) or whether they were open (e.g. ∍). The second task (Letters task) required participants to make the same decision about letter stimuli (e.g. **d** vs. **k**). The third task (Rhyme task) required participants to decide whether or not a prime or probe letter rhymed with the sound "zee" (e.g. **p** vs. **f**).

In response time (RT) and ERP component latency measures, positive priming is defined as a reduced average RT or ERP component latency to stimuli that were previously attended to (positive priming stimuli) compared to novel stimuli. Negative priming is defined as a longer average response latency or ERP component latency to repeated stimuli that were previously ignored (negative priming stimuli) compared to those for novel stimuli.

Hypotheses

(1) The letters in the Rhyme task were expected to take longer (i.e. longer RT) to categorize and evaluate than the letters in the Letters task, due to the greater amount of processing demanded by the task. Both the Rhyme and Letters stimuli were predicted to provide more information for processing and therefore take longer to categorize and evaluate than the Figures task stimuli. This was predicted to be reflected in the shortest N2 and P3 latencies for the Figures condition, then for the Letters task, and finally for Rhyme task.

(2) Positive priming effects are thought to emerge early on in processing while the latency of negative priming effects is thought to be beyond the range of the N1 and P2 ERP components. Therefore, it was predicted that N1 and P2 component latency would be related to positive priming but would not be related to negative priming effects. The N2 and P3 components occur in the hypothesized cognitive latency range (i.e. object level) of both negative and positive priming effects. Thus, the latencies of these components were predicted to show evidence of both negative and positive priming effects.

(3) An increase in the amount of processing carried out on stimuli from the Figures to the Letters to the Rhyme task was predicted to be related to an increased amount of coding among good readers. This was predicted to be reflected in an increase in the level of both negative and positive priming from the Figures to the Letters to the Rhyme task for good readers.

Poor readers were predicted to do well under the Figures and Letters tasks which demanded a response based on a visual aspect of stimuli. Poor readers were predicted to display as much or more positive and negative priming as good readers on these tasks and an increase in positive and negative priming from the Figures to the Letters task due to the greater familiarity of the Letters task stimuli. The phonological, rhyming decision of the Rhyme task was expected to be more difficult for poor readers than for good readers. This was predicted to be reflected in reduced positive and negative priming for poor readers compared to good readers on this task.

Method

Participants

Thirty-three [25 females (mean age = 20.24 s.d. = 2.49, Min = 18, Max = 31) and 8 males (mean age = 22.00 s.d. = 3.16, Min = 19, Max = 22)] first-year students at Brock University participated in the study as partial fulfillment of the requirements of a first-year course in psychology. One male participant's ERP results were not usable due to a failure to use a ground electrode during testing.

Materials and Test Procedure [1]

Copies or examples of all measures are given in the Appendix.

General assessment tests. The Brock Health and History Questionnaire was given to all participants to eliminate data from participants in the study who had any major blood flow or breathing problems or history of head injury.

The Test of Non-verbal Intelligence (TONI) (Brown, Sherbenou, & Dollar, 1982) was also administered as a measure of visual cognitive skills. This test was administered to ensure that the data of participants who had extremely poor visual cognitive skills data would not be included in analysis.

To establish reading level, participants were given two reading tests, the Biemiller's Test of Reading Processes (1981), and the Burns/Roe Informal Reading Inventory (1985). The portion of the Biemiller's test that was used tested the rate and accuracy of letter processing. The portions of the Burns/Roe used provided measures of reading achievement, word processing rate, and word recognition.

Participants were given a short test of colour discrimination ability consisting of an array of lines made up of coloured **X**s in two columns. Participants were asked to name the colour of each row of **X**s as quickly and accurately as possible. Time to name the colour of the series of rows was measured along with accuracy. This test was administered to ensure that only the data from participants who had good colour discrimination abilities would be included in analysis since the priming tasks involved decisions based on stimulus colour.

Tests thought to be sensitive to reading style. Studies that have been able to find differences in the serial and parallel processing abilities within poor reading groups use participants already classified as dyslexic by traditional criteria. In fact, Bialystok and Mitterer (1987) specifically selected poor parallel and serial processors from a larger sample of dyslexic individuals. The present study did not select poor readers based on a classification of extreme reading difficulty, but rather as the lower half of a continuum of high functioning adults. It was suspected that the limited range of reading abilities present among this sample might result in a failure to classify poor readers as either poor simultaneous or poor sequential readers. However, tests known to be sensitive to simultaneous and sequential processing were still used because of the proposed large differences in processing style between simultaneous and sequential processors.

Participants were given two tests intended to gauge their ability to process written language in a letter-by-letter (sequential) and in a whole-word (simultaneous) fashion. Tests used included the Woodcock Reading Mastery test (1973), and a regular- and exception-word and pseudoword reading task.

The Word-Attack portion of the Woodcock Reading Mastery Tests (1973) requires participants to read phonologically regular words. Scoring is based on speed and accuracy. This test has been used extensively, so participants' scores can be compared to test norms.

The word and pseudoword reading task used is similar to those used by Bialystok and Mitterer (1987). In both conditions of this task participants were seated in front of a computer monitor. White stimuli were presented on a black background on the computer screen for 300 ms. Stimuli consisted of 32 phonologically regular words and phonologically regular nonwords that were either homophones (n = 16) or non-homophones (n = 16). One half of participants were required to press the **F** key if a stimulus was judged to be a word and the **J** key if a stimulus was judged to be a non-word. For the other half of the participants key assignments were reversed. If a response was not made within 2000 ms of stimulus onset a buzzing sound was made by the computer followed by the next stimulus. In one condition stimuli and responses were as described above (the "silent" condition). In the other condition participants were required to count repetitively from one to ten while performing the task (the "concurrent counting" condition). This task was used in order to investigate the possibility that readers may differ in the extent to which they use visual and phonological processing styles.

Priming paradigm tasks. The study used a priming paradigm (Houghton and Tipper, 1994) to analyze the characteristics and time course of early and later processing associated with stimuli that were previously responded to, were previously ignored, or were novel. Priming tasks involved presentation of a Prime trial followed by a Probe trial. In both the Prime and the Probe trial colour was used to differentiate the target stimulus from the stimulus to be ignored. Targets were red and non-targets were blue.

Both Prime and Probe stimuli were presented near the centre of the computer screen with a latency of 300 ms. The interval between presentation of Prime stimuli and Probe stimuli was 2000 ms. After 3000 ms following the onset of the previous Probe stimulus, the next Prime trial was presented for 300 ms.

See Figure 2 for a graphical example of stimulus layout in Prime and Probe trials. Figure 3 shows possible Prime and Probe stimuli across tasks. In both the Prime and Probe trials one stimulus was presented in one of four positions defined by an imaginary 2 x 2 grid in the centre of the computer screen having a grey background. The other stimulus was positioned such that it was at one of the corners of the first stimulus' imaginary grid box. The top and bottom position of target and to-be-ignored stimuli within the grid was balanced for target and to-be-ignored stimuli to prevent participants from attending to a stimulus based on its location rather than its colour.

As has been mentioned, stimuli used were letters and "abstract" figures. There were three tasks in all, one using abstract figures (the Figures task) and the other two using letters (the Letters and Rhyme tasks). In all three tasks, participants made a keypress response to targets in Prime and Probe trials. All stimulus sets contained a total of 120 Prime-Probe trials.

For the Figures task and the Letters tasks, 50% of participants were asked to press the **F** key if the target (red) stimulus was closed (i.e. if it contained a closed loop, such as the letter **a** and the figure ϕ) and the **J** key if the target was open (i.e. if it contained no closed loop, such as the letter **k** and the figure ∍). For the other 50% of participants this key assignment was reversed. In the Rhyme task 50% of participants were required to press the **F** key if the target stimulus rhymed with the sound "zee" and the **J** key if the target stimulus did not rhyme with the sound "zee". The other 50% of participants received the opposite key assignment.

In Probe trials, targets were either (a) Prime targets, (b) ignored stimuli from Prime trials, or (c) novel Probes. This adds up to a frequency of 33% for each Probe type. Presentation of these three types of Probe targets was balanced in order to keep participants from forming expectancies based on recently presented targets. Novel Probes were balanced to contain 50% closed targets and 50% open targets. Non-targets were always novel in the Probe trial.

Variables measured during the priming tasks were average response times and ERPs associated with Probe stimulus responses.

ERP Measurement. ERP readings were made using gold electrodes placed at Fz, Cz, Pz, Oz, T_3, and T_4. The lateral electrodes were used in order to allow for the later investigation of the hypothesis that there are hemispheric differences in the location of simultaneous and sequential processing. All electrodes were referenced to linked ears and grounded via a mastoid site. Impedance was kept below 5 kOhms at initial testing and always remained below 10 kOhms by the end of testing. As a guideline for visual peak location, N1 was defined as the largest negative peak occurring between 80 and 150 ms following stimulus onset. P2 was defined as the largest positive peak following N1 and occurring between 150 and 250 ms. N2 was defined as the largest negative peak following P2 and occurring between 200 and 400 ms. P3 was defined as the largest positive peak following N2 and occurring between 300 and 700 ms. The amplitude and latency for each peak and for each participant were located by a computer program from within a visually defined latency range. All peaks were scored by one researcher.

Results

Assessment of Visual and Phonological Processing

The difference in number of errors for homophone nonwords and non-homophone nonwords in the silent condition of the word and pseudoword task was calculated for all participants. It was assumed that those who used phonological coding inflexibly would make more errors in making a word/nonword decision to the homophone nonwords (e.g. cote, frite) than to the nonhomophone nonwords (e.g. bule, noor) than those who used visual coding inflexibly. It was also predicted that those who used visual coding inflexibly would make more errors on the Word Attack test than those who used phonological coding inflexibly. The correlation between number of errors on the word and pseudoword task and the number of errors on the Word Attack test was calculated. A significant negative correlation would indicate that there was a relationship between visual and phonological coding. The correlation between these two error measures was not significant, r (n = 29) = -.16, $p > .1$. Since this correlation was not found to be significant, reading was not assessed in terms of visual and phonological processing but in terms of phonological task performance.

Paper and Pencil Tests [2]

Reading tasks were correlated (see Table 1). Time to read the first word list of the Biemiller task was found to correlated highly across other measures of reading speed such as the Burns/Roe (1985) best passage (the last passage on which a participant made 10% or fewer errors) time, r (n = 30) = .48, p < .01, the Burns/Roe poorest passage (the last passage on which a participant made 40% or fewer errors) time, r (n = 30) = .45, p = .01, and negatively correlated with the number of items read correctly on the Word-Attack test, r (n = 30) = -.47, p < .01. A histogram (see Figure 4) shows that the distribution of reading times for this word list is skewed toward the shorter latency end of the distribution. Two groups of cases can be seen, one centred around 14.5 seconds and the other around 18 seconds. A median split of this variable at 17.18 seconds was used to divide the participants into a poor reading group (n = 17) and a good reading group (n = 16). The lower half of this group (mean = 14.72, s.d. = 1.81) is more homogeneously distributed than the upper half of this group (mean = 21.01, s.d. = 3.62). A t-test showed that the means of these two groups are significantly different from each other, t (unequal variances adjusted df = 21.78) = -6.26, $p < .001$, although the seconds-per-word reading rates of the good reading group (.29 seconds per word) and poor reading group (.42 seconds per word) are both within the normal range for this test. A t-test showed that these two groups also performed significantly differently from each other on the Word Attack test, t (31) = 2.95, $p < .01$, a common indicator of phonological reading skills. Thus, while both poor reading and good reading groups performed within the normal Biemiller test range, the poor reading group still read more slowly and made more phonological errors than the good reading group. These results suggest that the reading differences between the two groups do not indicate gross differences in reading skills so much as more subtle differences in reading fluency. The terms "good readers" and "poor readers" are therefore used to refer to differences in fluency. Several regression analyses were run to examine RT results when reading level was treated as a continuous variable and compared with results achieved using categorical ANOVA analysis. These analyses produced similar results and are discussed in more detail later.

Priming Tasks

Specific predictions were made about positive and negative priming effects. Therefore, rather than calculating omnibus ANOVAs across priming conditions, tasks, and reading groups, 3-way ANOVAs were calculated for RT latency and ERP amplitude and latency results to investigate positive and negative priming effects (Priming) across priming tasks (Task) and between reading groups (Group). When interactions with Task were significant, 2-way ANOVAs were calculated in order to investigate priming effects within each task (Figures, Letters, and Rhyme) and between reading groups. A summary of the means used in ANOVA comparisons is found in Table 2. A summary of the results is found in Table 3.

If an ERP peak could not be unambiguously found within its latency range, it was scored as missing. The greatest amount of missing data primarily involved N1. N1 is thought to be related to stimulus detection. It is possible that the presentation of two stimuli in the Prime and

Probe trials caused variation in stimulus detection latency, causing N1 to be diminished and rendered unscorable when averaged.

Since it was possible that the number of observations under a 3-way ANOVA could be smaller than under its 2-way ANOVAs due to differing amounts of missing data, an arbitrary criterion was established to ensure that the means in the 2-way ANOVAs did not differ markedly from those in the 3-way ANOVAs. For priming RT and ERP peak latency the cutoff difference was +/- 10 ms and for ERP amplitude the cutoff difference was +/- 0.5 microvolts. If the cutoff value was exceeded, the 2-way ANOVA was recalculated using only the participants from the 3-way ANOVA (resulting in a lower N in that analysis). The cutoff rule was not used with N1 because the reduction in reading group size would have precluded any group comparisons in the 2-way ANOVAs.

RT and ERP Latencies Across Tasks

3 X 3 ANOVAs across tasks (Figures, Letters, Rhyme) and stimulus conditions (positive, negative and novel) were performed in order to investigate main effects of RT and ERP latencies across tasks. Response time was found to increase significantly from the Figures (618.12 ms) to the Letters (629.02 ms) to the Rhyme task (676.90 ms), F (2, 54) = 26.15, $p < .001$. N1 latency was found to be greatest in the Letters task, F (2, 28) = 2,79, $p < .05$. P2 latency was not found to differ across tasks, F (2, 44) = 2.47, $p > .05$. N2 latency was found to increase from the Figures (320.24 ms) to the Letters (322.74 ms) to the Rhyme task (352.19 ms), F (2, 44) = 5.39, $p <$,01, as was P3 latency, F (2, 46) = 10.73, $p < .001$ (479.87 ms, 491.46 ms, and 535.30 ms respectively).

Response Time

Positive priming. A 3-way ANOVA was performed to compare average response times for positive-priming versus novel stimuli (see Figure 5) across priming tasks (Figure, Letter, and Rhyme) for good and poor readers. Significant effects were found for Task (mean RT change over Figure, Letter, and Rhyme conditions), F (1, 27) = 13.98, p, $< .001$, for Priming (Mean RT difference between the Positive and Novel conditions), F (1, 27) = 144.49, p, $< .001$, for Task x

Priming, $F(2, 54) = 4.86, p, < .05$, and for Group x Task x Priming, $F(2, 54) = 5.03, p, < .05$. The task effect was due to an increase in mean RT from the Figures to the Letters to the Rhyme condition. The Priming effect was due to a decreased RT to Probe stimuli compared to Novel stimuli. The Task x Priming effect was due to an increase in priming from the Figures to the Letters to the Rhyme condition. Finally, the Group x Task x Priming effect was due to the good readers showing a constant level of positive priming but the poor readers showing a level of positive priming that was lower than that of the good readers in the Figures and Letters tasks and exceeded the good readers in the Rhyme condition (see Figure 6). The difference in positive priming effects between good and poor readers was particularly pronounced in the Figures task. In order to test whether reading speed predicted positive priming in the Figures task, time to read the first word list of the Biemiller task was correlated with a score made up of the difference between average novel condition RT and positive priming condition RT. This correlation was significant, r (n = 30) = -.44, $p < .05$.

Two-way ANOVAs were performed on individual priming tasks (Figure, Letter and Rhyme). For the Figures task significant effects were found for Priming, $F(1, 28) = 94.89, p < .001$, and for Group x Priming, $F(1, 28) = 5.97, p < .05$. For the Letters task a significant effect was found for Priming, $F(1, 27) = 93.05, p < .001$. For the Rhyme task a significant effect was found for Priming, $F(1, 27) = 92.97, p < .001$.

Negative priming. The amount of negative priming in ms is shown in Figure 6. A 3-way ANOVA comparing response time across tasks and between poor and good readers produced significant effects for Task, $F(2, 54) = 34.70, p < .001$, for Priming, $F(1, 27) = 26.24, p < .001$, and for Task x Priming, $F(2, 54) = 5.07, p < .05$. As with the positive priming condition, the Task effect was due to an increase in mean RT from the Figures to the Letters to the Rhyme condition. The Priming effect was due to an overall larger RT for negative priming stimuli than for novel stimuli, indicating, as predicted, that negative priming stimuli were associated with negative priming effects. The Task x Priming effect was due to an increase in the level of negative priming effects from the Figures to the Letters to the Rhyme condition. This Task X

Priming effect is consistent with predictions that the increased familiarity of stimuli in the Figures to the Letters and of depth of processing from the Letters to the Rhyme task would lead to an increase in negative priming across tasks.

For the Figures task no significant effects were found. For the Letters task a significant effect was found for Priming, $F\ (1, 27) = 6.28, p < .05$. For the Rhyme task a significant Priming effect was also found, $F\ (1, 28) = 30.46, p < .001$. Thus, a negative priming effects was not found in the Figures condition, emerged in the Letters condition, and was present more strongly yet in the Rhyme condition, making more explicit the cause of the Task X Priming negative-priming effect.

Regression analysis of positive and negative RT results across tasks. In order to assess the possibility that an analysis that treated reading ability as a continuous variable would lead to different results from an analysis that treated reading as a categorical variable, a regression analysis of the Reading Level x Priming was performed on both positive and negative priming RT data for each task. These analyses showed a significant reading level x positive Priming effect for the Figures task, $R^2 = .049$, $F\ (1, 27) = 6.38, p < .05$. These results are analogous to the significant Group x Priming ANOVA effects. As with the ANOVA results, no other reading level x Priming effects were found. Since the dichotomizing appears to have captured the salient variance in reading score adequately, we continued with ANOVA designs.

ERP Components

Mean amplitude of N1, P2, and N2 across tasks was maximal at Cz. Mean amplitude of P3 across tasks was maximal at Pz. Amplitude and latency results for N1, P2, and N2 are reported at Cz and for P3 at Pz as is standard. See Table 2 for a listing of the mean amplitudes and latencies of the N1, P2, N2 and P3 components across priming tasks and between reading groups. [3]

N1. See Figure 7 for a graphical representation of N1 latency for the Figures, Letters, and Rhyme conditions, for Good and Poor readers. No significant main effects or interactions were found for positive priming in either the 3-way or 2-way ANOVAs.

Contrary to predictions in the negative priming condition, a significant Priming effect was found for N1 latency F (1, 14) = 6.11, $p < .05$. This was due to an increased N1 latency to Negative priming stimuli compared to Novel stimuli. The possibility that this effect was due to extreme scores was investigated by examining participants' N1 latency scores across priming tasks. One participant in the good reading group had novel and negative priming latencies that differed by 45 ms or more across tasks, compared to a mean and S.D. of 17.77 and 4.24. The 3-way ANOVA was repeated following the removal of the data from this participant as well as the data from any participants who had an N1 latency lower than the cutoff of 80 ms. The result was a strengthening of the negative priming effect, F (1, 10) = 13.02, $p < .01$.

P2. See Figure 8 for a graphical representation of P2 latency for the Figures, Letters, and Rhyme conditions, for good and poor readers. A 3-way ANOVA on P2 positive priming latency revealed a significant Group x Prime effect, F (1, 23) = 5.05, $p < .05$, caused by a decreased P2 latency in the Positive condition compared with the Novel condition for the good readers but not for the poor readers.

A 3-way ANOVA on P2 negative priming latency revealed a significant effect for Task, F (2, 46) = 3.33, $p < .05$. This seems to have been caused by a reduced P2 latency in the Letters condition.

N2. See Figure 9 for a graphical representation of N2 latency for the Figures, Letters, and Rhyme conditions, for good and poor readers. N2 latencies for positive priming stimuli across tasks and between reading groups were analyzed using a 3-way ANOVA. Significant effects were found for Task, F (2, 46) = 3.35, $p < .05$, and for Priming, F (1, 23) = 5.04, $p < .05$. The Task effect was caused by an increase in N2 latency from the Figures to the Letters to the Rhyme condition. The Priming effect was caused by mean N2 latencies that were longer for the Novel conditions than the Positive conditions across tasks.

A 3-way ANOVA on negative priming stimuli revealed a significant Task effect, F (2, 46) = 8.14, $p < .01$. As with the Positive 3-way task effect, the Negative task effect was caused by an increase in mean N2 latency from the Figures to the Letters to the Rhyme condition.

P3. See Figure 10 for a graphical representation of P3 latency for the Figures, Letters, and Rhyme conditions, for good and poor readers. A 3-way ANOVA on P3 latency for positive priming stimuli revealed a significant effect of Task, $F(2, 48) = 7.40$, $p < .01$, and of Priming, $F(1, 24) = 26.54$, $p < .001$. The Task effect was caused by an increase in P3 latency from the Figures to the Letters to the Rhyme condition. The Priming effect was caused by a decreased P3 latency in the Positive condition compared to the Novel condition.

Using a 3-way ANOVA to investigate P3 latency effects for negative priming stimuli, a significant Task effect was found, $F(2, 48) = 10.68$, $p < .001$, caused, as with the Positive condition, by an increase in P3 latency from the Figures to the Letters to the Rhyme condition.

Amplitude Effects

Although we had no prior hypotheses concerning ERP component amplitudes the amplitude results are included here for completeness.

N1. See Figure 11 for a graphical representation of N1 amplitude for the Figures, Letters, and Rhyme conditions, for good and poor readers. A 3-way ANOVA on N1 amplitude revealed no significant 3-way effects for positive priming. A significant negative priming effect was also found for Group x Priming, $F\ (1, 14) = 5.74$, $p < .05$. This Group x Priming effect was due to an increase in N1 amplitude from the Novel to the Negative condition for good readers and a decrease for poor readers.

P2. See Figure 12 for a graphical representation of P2 amplitude for the Figures, Letters, and Rhyme conditions, for good and poor readers. A 3-way ANOVA revealed significant positive priming P2 amplitude effects for Group, $F\ (1, 23) = 9.67$, $p < .01$, for Task, $F\ (2, 46) = 6.31$, $p < .01$, and for Task x Priming, $F\ (2, 46) = 4.55$, $p < .05$. The group effect was due to a larger P2 amplitude for poor readers than for good readers. The Task effect was due to mean P2 amplitude that increased from the Figures to the Letters to the Rhyme condition. Finally, the Task x Priming effect was due to a lower P2 amplitude in the Positive condition than in the Novel condition, this difference being greatest in the Letters condition, then in the Figures condition, then in the Rhyme condition.

No significant 2-way ANOVA positive priming effects were found for the Figures task or for the Rhyme task. For the Letters task a significant Group effect was found, $F\ (1, 26) = 15.20$, $p < .001$, due to a larger average P2 amplitude for poor readers. It is likely that this increased P2 amplitude for poor readers was driving the 3-way Group x Priming effect.

Significant 3-way ANOVA effects were found for Group, $F\ (1, 23) = 7.98$, $p < .05$, for Task, ($F\ (2, 46) = 10.59$, $p < .001$, and for Group x Task, $F\ (2, 46) = 4.14$, $p < .05$. As with the Positive priming condition, the Group effect was due to a larger P2 amplitude in the poor readers than in the good readers and the Task effect was due to an average P2 amplitude that increased from the Figures to the Letters to the Rhyme condition.

The only significant 2-way ANOVA effect found was in the Letters task for Group, $F\ (1, 27) = 13.25$, $p < .01$. It is this effect that seems to have been driving the 3-way Group x Task effect.

N2. See Figure 13 for a graphical representation of N2 amplitude for the Figures, Letters, and Rhyme conditions, for good and poor readers. Using a 3-way ANOVA on positive priming for N2 amplitude, a significant effect for Task ($F\ (2, 46) = 3.48$, $p < .05$, was revealed, caused by an elevated N2 amplitude in the Rhyme condition. A significant N2 amplitude effect was also found for Task, $F\ (1, 23) = 12.36$, $p < .01$, due to reduced amplitude to positive priming stimuli compared to novel stimuli.

A 3-way ANOVA on negative priming for N2 amplitude revealed a significant effect for Task, $F\ (2, 46) = 8.14$, $p < .01$, due to a larger N2 amplitude in the Rhyme condition than in the Figures and Letters conditions.

P3. See Figure 14 for a graphical representation of P3 amplitude for the Figures, Letters, and Rhyme conditions, for good and poor readers. A 3-way ANOVA on P3 amplitude for positive priming stimuli revealed a significant effect of Task ($F\ (2, 48) = 10.70$, $p < .001$), caused by a decrease in P3 amplitude in the Rhyme condition compared to the Figures and Letters conditions.

A 3-way ANOVA on P3 amplitude for negative priming stimuli revealed a significant effect of Task (F (1, 23) = 6.52, $p < .01$), as with the Positive 3-way Task effect, due to a decrease in P3 amplitude in the Rhyme condition compared to the Figures and Letters conditions.

Discussion

This thesis addresses three questions. The first question deals with how the three priming tasks differ from each other both in terms of response time and in terms of ERP component latencies. The second question concerns the timing locus of positive and negative priming effects as measured ERP component latencies. The third question deals with how poor and good readers differ from each other across tasks and in negative and positive priming.

The Three Tasks

Three tasks were used in this thesis study. These tasks include a Figures task that employed abstract figures and a Letters and Rhyme task that used letter stimuli. Both the Figures and Letters tasks required participants to make an open/closed response about the target stimuli. The Rhyme task required participants to make judgements about whether or not the target stimuli rhymed with the sound “zee”.

It was found that time to respond to stimuli increased from the Figures to the Letters to the Rhyme task. This response time increase across tasks was mirrored by general increases in N2 and P3 latencies. This supports the hypothesis that increasing the amount of stimulus processing lengthens the time it takes for them to be processed at the object representation level.

Priming Effects Across the Three Priming Tasks

Positive priming effects. A decrease in the time for a response to be made to previously-responded-to prime stimuli compared to novel stimuli (a positive priming effect) was found across priming tasks, consistent with the models of both Posner (1985) and Tipper (Houghton & Tipper, 1994). This effect was also found for N2 latency and P3 latency and for P2 latency with good readers. These ERPs provided information on on-going processing not available from previous studies which used RT measures only as indicators of positive priming. This effect of a faster response and ERP component latency to a previously-responded-to stimulus is consistent with the hypothesis that positive priming would occur across priming tasks and relatively early in the processing. The ERP P2 effect indicates that a processing advantage is gained because of positive priming as early as 200 ms after stimulus presentation.

Negative priming effects. An increase in response time to previously ignored stimuli compared to novel stimuli was found across tasks. Thus, consistent with previous work (e.g. Hougton & Tipper, 1994; Neumann & DeSchepper, 1991; Gernsbacher & Faust, 1991), the paradigm used was successful in eliciting the negative priming effect. However, the only negative priming effect that was found to occur across tasks for ERP component latency was for N1 latency. This effect is contrary to predictions. It remained even following the elimination of extreme cases. However, no negative priming latency effects were found in P2, N2, or P3, i.e. the slowing of stimulus processing following negative priming is not found in ERP components as late as 500 ms. Therefore, this N1 latency effect is not interpretable under the negative priming paradigm and awaits further replication.

The lack of negative priming latency effects even as late as the P3 supports the popular hypothesis that positive priming effects emerge earlier on in processing than negative priming effects and also suggests that the locus of the negative priming effect is after stimulus evaluation and possibly during response selection or initiation. McCarthy and Donchin (1981) showed that stimulus-response incompatibility delays RT without affecting P3 latency. Thus, these results are compatible with a response-selection or response-initiation locus of negative priming.

How Poor and Good Readers Differ Across Tasks and in Negative and Positive Priming.

According to Houghton and Tipper's (1994) model of priming, perceptual representations are enhanced and inhibited in the Prime trial based on criteria dictated by task demands (stimulus colour in all three tasks of this study). Enhancement and inhibition of Prime stimuli are also proposed to require perceptual representations of both the attended and ignored stimuli. Perceptual representations that are more well-defined should result in more effective inhibition and stronger negative priming results.

Contrary to these predictions, the pattern of negative priming effects was the same across tasks for both poor and good readers. It was predicted that negative priming would increase for poor and good readers from the Figures to the Letters. This prediction was based on the proposal that early processing based on a visual aspect of stimuli would be more thorough for the familiar Letters task stimuli and would lead to perceptual representations that were more well-defined and therefore effectively inhibition for both poor and good readers. It was predicted that good readers would more readily and easily deal with the Rhyme task stimuli according to their phonological characteristics than poor readers. This was expected to result in perceptual representations that were more well-defined and more effectively inhibited for good readers and less well-defined and effectively inhibited for poor readers. Thus, an increase in negative priming was predicted from the Letters to the Rhyme task for good readers and decrease in negative priming was predicted for poor readers. The negative priming results across tasks indicate that the processes causing negative priming were statistically equivalent for poor and good readers, although examination of Figure 6 indicates that the pattern of the means was appropriate for such an interaction.

Good readers displayed equivalent positive priming effects from the Figures to the Letters to the Rhyme task while poor readers displayed an increase in positive priming from the Figures to the Letters to the Rhyme task. In the Figures task positive priming was significantly smaller for poor readers (48 ms) than for good readers (80 ms). In the Letters task, positive priming was also smaller for poor readers (72 ms) than for good readers (86 ms). In the Rhyme task positive priming effects were greater in poor readers (102 ms) than for good readers (80 ms). RT to novel stimuli differed between poor and good readers by only -3 ms in the Figures task, 7 ms in the Letters task, and 22 ms in the Rhyme task. This suggests that general visual processing speed is not superior in poor readers. RT to positive priming stimuli differed between poor and good readers by 29 ms in the Figures task, 21 ms in the Letters task, and -1 ms in the Rhyme task. Thus, the positive priming effect difference between poor and good readers was due to the amount of positive priming displayed by poor and good readers in the Figures and Letters tasks and to a difference in time to respond to novel stimuli in the Rhyme task. These findings are contrary to predictions.

It was predicted that for good readers the depth of stimulus processing would be greater in the Letters task than in the Figures task and greater yet in the Rhyme task, leading to an increase in positive priming from the Figures to the Letters to the Rhyme task. Poor readers were predicted to be "captured" by the visual characteristics of stimuli and do well on tasks based on a visual aspect of a stimulus. Thus positive priming was predicted to increase from the Figures to the Letters task for poor readers and be equivalent with positive priming for good readers. The Rhyme task demanded a response based on a phonological aspect of stimuli. According to Siegel, Share, and Geva (1995), poor readers perform poorly on tasks that require a response based on phonological aspect of stimuli. Therefore, it was predicted that poor readers would show a decrease in positive priming in the Rhyme task relative to the Figures and Letters tasks.

The positive priming results of this study fail to support Siegel's proposal that poor readers perform well on tasks requiring a response based on a visual aspect of stimuli and poorly on tasks requiring a response based on a phonological aspect of stimuli. Poor readers were instead found to increase in positive priming effects with an increase in stimulus familiarity and task demands. The finding that good readers showed constant positive priming across tasks suggests that good readers processed stimuli deeply enough to achieve maximal positive priming regardless of stimulus familiarity and tasks demands. Thus, poor readers do not seem to differ from good readers in their ability to deal with the phonological aspects of stimuli in this task, but rather in how readily they deeply process visual stimuli with the less linguistic task demands. Poor readers do not show evidence of deeper processing on the more visual and less linguistic tasks, nor do they seem to be "captured" by the visual stimuli. It may be that good readers displayed constant positive priming across tasks because they elaborated on stimulus information, carrying out verbal coding even with nonverbal stimuli such as Figures task stimuli.

Amplitude Effects

Although predictions were not made about ERP amplitude effects several amplitude effects occurred that deserve some comment. The amplitude of the P2, N2, and P3 components were found to increase from the Figures to the Letters to the Rhyme task. This effect mirrored the latency increase across tasks for P2, N2, and P3. This may suggest that an increasing amount of processing across tasks was reflected both in increased processing time and in an increase in the processes that lead to ERP component amplitude. These processes may include the recruitment of more neurons to complete a task and/or an increased synchronization of firing of neurons driving ERP components.

Poor readers were found to have greater P2 and P3 amplitudes than good readers. This may indicate that in poor readers more neurons were being recruited to complete the priming task decisions than in good readers. If this is so it does not seem to have given poor readers a performance advantage over good readers. In fact, RT latency positive priming results suggest that good readers were dealing with stimulus information and task demands more effectively that poor readers.

Conclusions

Consistent with predictions, the latency of RT and ERP measures increased from the Figures to the Letters to the Rhyme task. Thus, the more complex tasks, as hypothesized, took longer to process. Positive and negative priming effects also increased across tasks, especially for the poor readers. This is consistent with the hypothesis that priming effects would increase with task complexity. ERP latency measures also showed that positive priming effects occurred earlier in the processing than negative priming effects. This supports Tipper's (Houghton and Tipper, 1994) negative priming model and is consistent with Posner's (1981) model of attention. Contrary to predictions, poor and good readers were not found to differ across tasks in negative priming effects, suggesting that the source of poor reading is not necessarily attributable to dysfunctional inhibitory processes in visual attention. Poor and good readers were found to differ in positive priming effects. The pattern of positive priming effect variation across tasks was contrary to predictions for both poor and good readers and suggests that poor readers may show a disadvantage in how readily they deeply process nonlinguistic visual stimuli.

Footnotes

1 **Additional Tests Used**. For reasons beyond this thesis additional tests were administered and will not be discussed in the body of the text

Paper and pencil tasks. Participants were given the Stroop task (Stroop, 1935) which tests for the level of conflict between a word's spelling identity and its ink colour identity (RED, GREEN, BLUE, TAN). In this task there are four stimulus sets, each printed on a sheet in a 4x28 row x column arrangement for a total of 112 stimuli in each condition. The first condition required participants to read the names of colour words whose ink colours conflicted with the spelling identity of their words (e.g. read the word **BLUE** printed in green ink). This is considered to be a test of the interference of a word's ink identity on its spelling identity. In the second condition participants were asked to name the colour of the ink in which the colour words were printed. Again in this condition, the name of the ink colour and the colour word conflicted (e.g. name the ink colour green in which the word **BLUE** is printed). This is considered to be a test of the interference of a word's spelling identity on its colour identity and is thought to involve selective attention. This test was administered because it requires a rapid phonological response to visual stimuli. It was expected that poor readers would take longer to name the word colours in the second condition than good readers.

ERP tasks. In addition to the priming tasks, ERPs were taken during the administration of a CNV task and an auditory oddball task.

The CNV task is a test of sustained attention and the auditory oddball task is a test of attention to rare tones. For a description of this task, see Segalowitz, Wagner, and Menna (1992). The duration oddball task was conducted to compare the ERPs of poor and good readers on a simple auditory discrimination task. In this task, participants were required to press the spacebar on a computer keyboard when they detected a short tone that occurred amidst a series of long tones. The ratio of long tones to short tones was .20 to .80. The CNV and duration oddball tasks were not directly related to the focus of this thesis and will not be discussed further here.

2 **Results Peripheral to Main Hypotheses**

Time to name the colours of coloured words in the Stroop task was correlated with time to read the letter list, word lists, and stories in the Biemiller task. All correlations between this Stroop task measure and Biemiller task measures were significant. The strongest correlations were between Stroop naming time and the first word list, r (n = 30) = .66, $p < .001$, and the second word list, r (n = 30) = .66, $p < .001$. This was also confirmed by a t-test comparing the mean colour naming time for good readers (46.60 s) and poor readers (54.61 s), t (31) = -2.60, $p < .05$. These results are consistent with the expectation that poor readers would have difficulty on tasks requiring rapid phonological access to visual stimuli.

3 N2 always occurred prior to RT in all participants. Out of a total of 161 P3 latency data points, 151 (93.4 %) occurred prior to RT. These results suggest that processes related to stimulus classification were maximal prior to RT and that processes related to stimulus evaluation were usually maximal prior to RT but did not need to be completed prior to response.

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Table 1

Correlation Table of Correlations Between Reading Measures

	BLS1TIM	BST2TIM	BLS2TIM	COMGTIM	COMGWPM	COMPTIME	COMPWPM	WATT_50
BST1TIM	.790 ***	.943 ***	.847 ***	.554 **	-.724 **	.431 *	-.598 ***	-.282
BLS1TIM	•	.856 ***	.935 ***	.476 **	-.570 **	.445 *	-.608 ***	-.474 **
BST2TIM		•	.911 ***	.542 **	-.706 ***	.442 *	-.602 ***	-.358 *
BLS2TIM			•	.521 **	-.619 ***	.476 **	-.632 ***	-.471 **
COMGTIM				•	-.831 ***	.724 ***	-.759 ***	-.012
COMGWPM					•	-.531 **	.708 ***	.159
COMPTIM						•	-.911 ***	-.064
COMPWPM							•	-.067

* $p < .05$ ** $p < .01$ *** $p < .001$

BST1TIM - Biemiller Test Story 1 Time
BLS1TIM - Biemiller Test Word List 1 Time
BST2TIM - Biemiller Test Story 1 Time
BLS2TIM - Biemiller Test Word List 1 Time
COMGTIM - Reading Comprehension Good Comprehension Story Time (on Last Story With 20% or Fewer Errors)
COMGWPM - Reading Comprehension Good Comprehension Story Time (on Last Story With 20% or Fewer Errors)
COMPTIM - Reading Comprehension Poor Comprehension Story Time (on Last Story With 40% or Fewer Errors)
COMPWPM - Reading Comprehension Poor Comprehension Story Time (on Last Story With 40% or Fewer Errors)
WATT_50 - Woodcock-Johnson Word Attack Task Number of Correctly Read Nonwords out of 50

Table 2

Priming task means across conditions (Pos, Neg, Nov). Measures are RT latency (msec) and N1, P2, N2 and P3 amplitude (microvolts) and latency (ms) for Good Readers (GR) and Poor Readers (PR).

GROUP	Figures Pos	Figures Nov	Figures Neg	Letters Pos	Letters Nov	Letters Neg	Rhyme Pos	Rhyme Nov	Rhyme Neg
RT GR	559.83	640.00	642.08	561.43	647.11	661.16	606.78	686.35	722.53
RT PR	589.49	637.11	643.07	582.26	654.06	672.15	605.81	708.03	734.68
RT Both	573.12	638.70	642.52	570.77	650.22	666.08	606.35	696.37	727.98
N1A GR	-2.041	-1.64	-2.21	-2.40	-2.44	-2.36	-1.68	-1.89	-2.53
N1A PR	-1.71	-4.60	-1.77	-2.08	-2.42	0.34	-2.49	-1.96	-1.37
N1A Both	-1.89	-2.97	-2.04	-2.26	-2.44	-1.36	-2.04	-1.92	-2.10
N1L GR	125.00	117.95	124.00	114.77	114.09	114.75	126.59	119.09	119.75
N1L PR	117.77	114.44	110.00	106.11	109.72	113.75	112.22	112.77	121.66
N1L Both	121.75	116.38	118.75	110.88	112.12	114.38	120.13	116.25	120.47
P2A GR	5.09	4.75	5.52	4.98	6.57	5.61	7.09	6.39	5.93
P2A PR	8.95	7.47	8.26	9.79	12.59	12.09	10.20	10.06	9.21
P2A Both	6.94	6.06	6.94	7.29	9.46	8.98	8.58	8.15	7.64
P2L GR	200.00	208.46	205.21	186.73	201.15	197.08	203.27	212.81	206.04
P2L PR	218.75	219.79	224.62	217.50	211.88	198.85	216.88	216.67	206.53
P2L Both	209.00	213.90	215.30	201.50	206.30	198.00	209.80	214.70	206.30
N2A GR	-5.14	-5.67	-5.84	-5.57	-5.95	-6.27	-5.18	-8.03	-7.778
N2A PR	-2.49	-5.56	-3.29	-2.28	-3.06	-.957	-3.82	-5.83	-5.772
N2A Both	-3.87	-5.62	-4.52	-3.99	-4.56	-3.509	-4.53	-6.97	-6.735
N2L GR	313.85	333.85	323.96	333.08	327.69	324.17	346.15	354.04	372.50
N2L PR	313.13	330.21	309.04	317.92	318.54	317.31	338.13	357.71	341.73
N2L Both	313.50	332.10	316.20	325.80	323.3	320.60	342.30	355.80	356.50
P3A GR	8.548	9.94	9.03	8.52	9.79	9.14	7.21	6.72	6.78
P3A PR	11.61	12.73	12.16	13.17	14.38	12.01	10.29	10.25	11.39
P3A Both	9.96	11.23	10.59	10.67	11.91	10.58	8.63	8.35	9.08
P3L GR	459.46	498.39	482.12	471.96	510.00	518.08	503.57	545.71	553.85
P3L PR	470.63	497.71	473.85	463.13	503.13	473.08	479.38	573.75	553.08
P3L Both	464.62	498.08	477.98	467.89	506.83	495.58	492.40	558.65	553.46

Table 3

Significant 3-way and 2-way ANOVA results for RT and ERP analyses.

ANOVA	3-Way Pos	3-Way Neg	FigPos	FigNeg	LetPos	LetNeg	RhymPos	RhymNeg
RT	Task *** Prime *** Task x Pr * Gr x Task x Pr *	Task *** Prime *** Task x Prime *	Prime *** GrXPr *	--	Prime ***	Prime *	Prime ***	Prime ***
N1Amp	--	GrXPr *						
N1Lat	--	Prime *						
P2Amp	Group ** Task ** Task x Pr *	Group * Task *** Gr x Task *	--	--	Group ***	Group **	--	--
P2Lat	Gr x Pr *	Task *						
N2Amp	Task * Prime **	Task **						
N2Lat	Task * Prime *	Task **						
P3Amp	Task ***	Task **						
P3Lat	Task ** Prime ***	Task ***						

* $p < .05$; *** $p < .001$; ** $p < .01$; -- Non-significant result

Figure 1

Schematic of Early and Late Processing

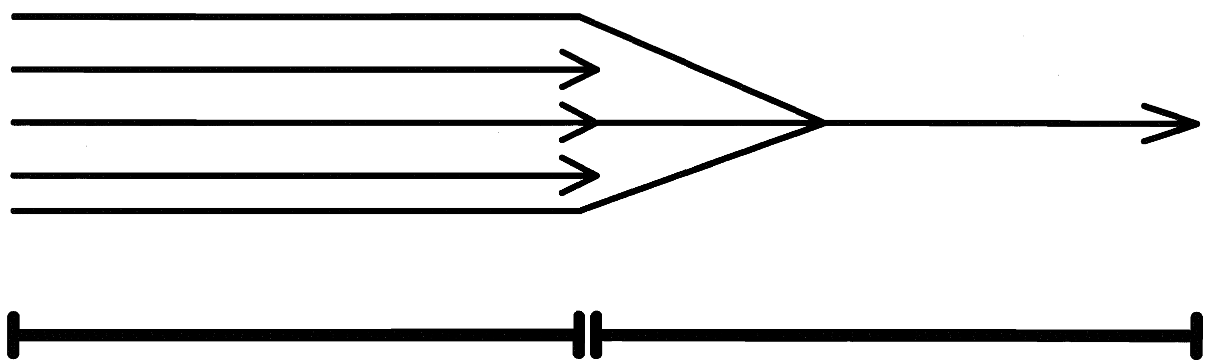


Figure 2

Stimulus layout of Prime and Probe trial stimuli in the Figures tasks.

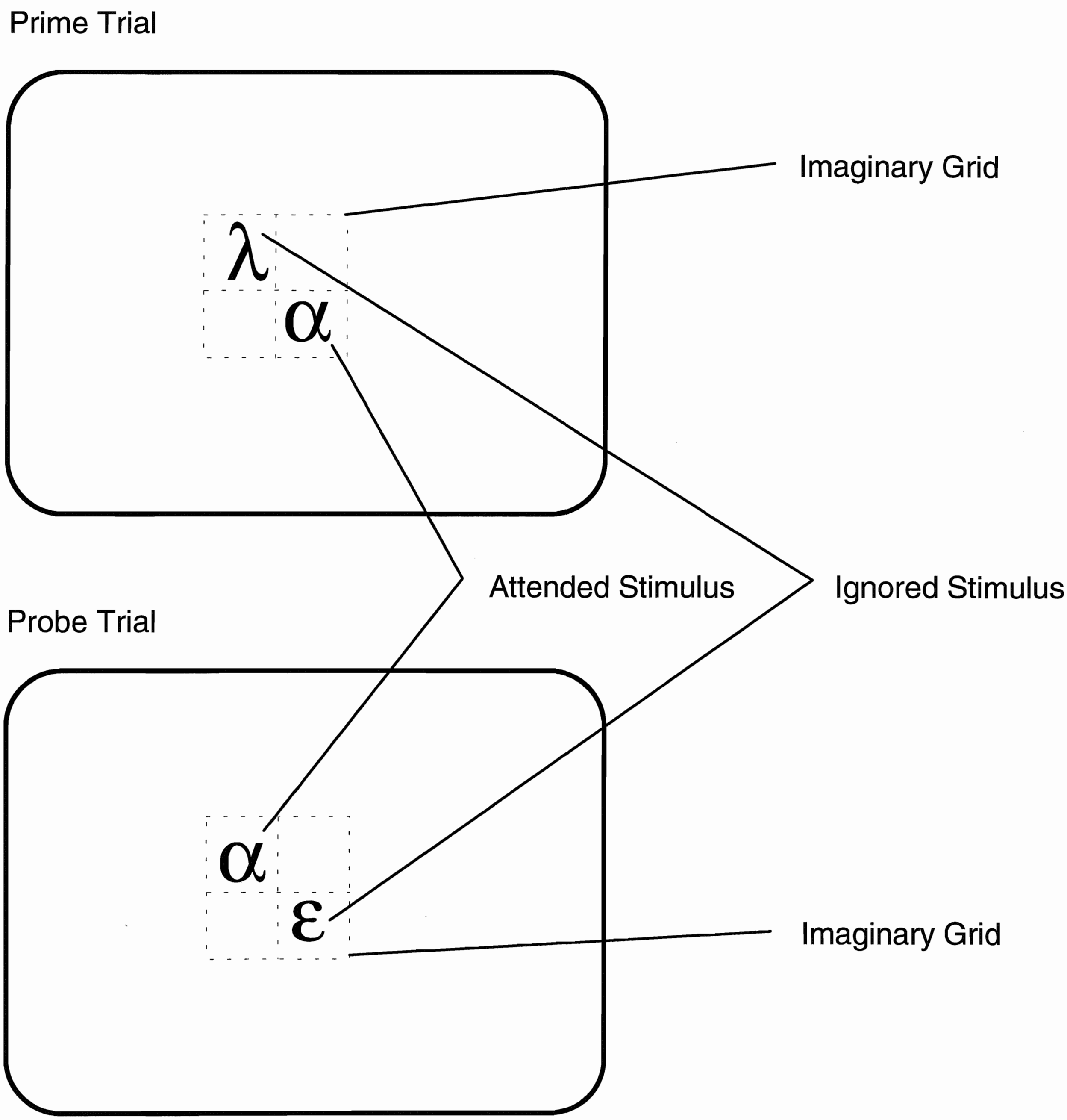


Figure 3

a) abstract symbol stimuli to be categorized as having an enclosed space or not (b) letter stimuli to be categorized as having an enclosed space or not (c) letter stimuli requiring a rhyming decision. Assume that upper stimuli are to-be-attended (targets) stimuli and that lower stimuli are to-be-ignored stimuli (non-targets).

i) is the prime trial in (a), (b), and (c); (ii), (iii), and (iv) are possible probe trials. Specifically, (ii) prime target stimulus becomes probe target; (iii) prime ignored stimulus becomes probe target; (iv) probe target is novel.

a)	Φ	Φ	≈	Ω		Θ *
					or	
	≈	≡	Θ	Θ		Ω
	i)	ii)	iii)	iv)		

b)	a	a	j	w		d *
					or	
	j	k	d	d		w
	i)	ii)	iii)	iv)		

c)	a	a	p	c		k *
					or	
	p	k	k	k		c
	i)	ii)	iii)	iv)		

* - assume upper stimuli to be attended stimuli and lower stimuli to be ignored stimuli.

Figure 4

Histogram of reading times for Biemiller word list 1.

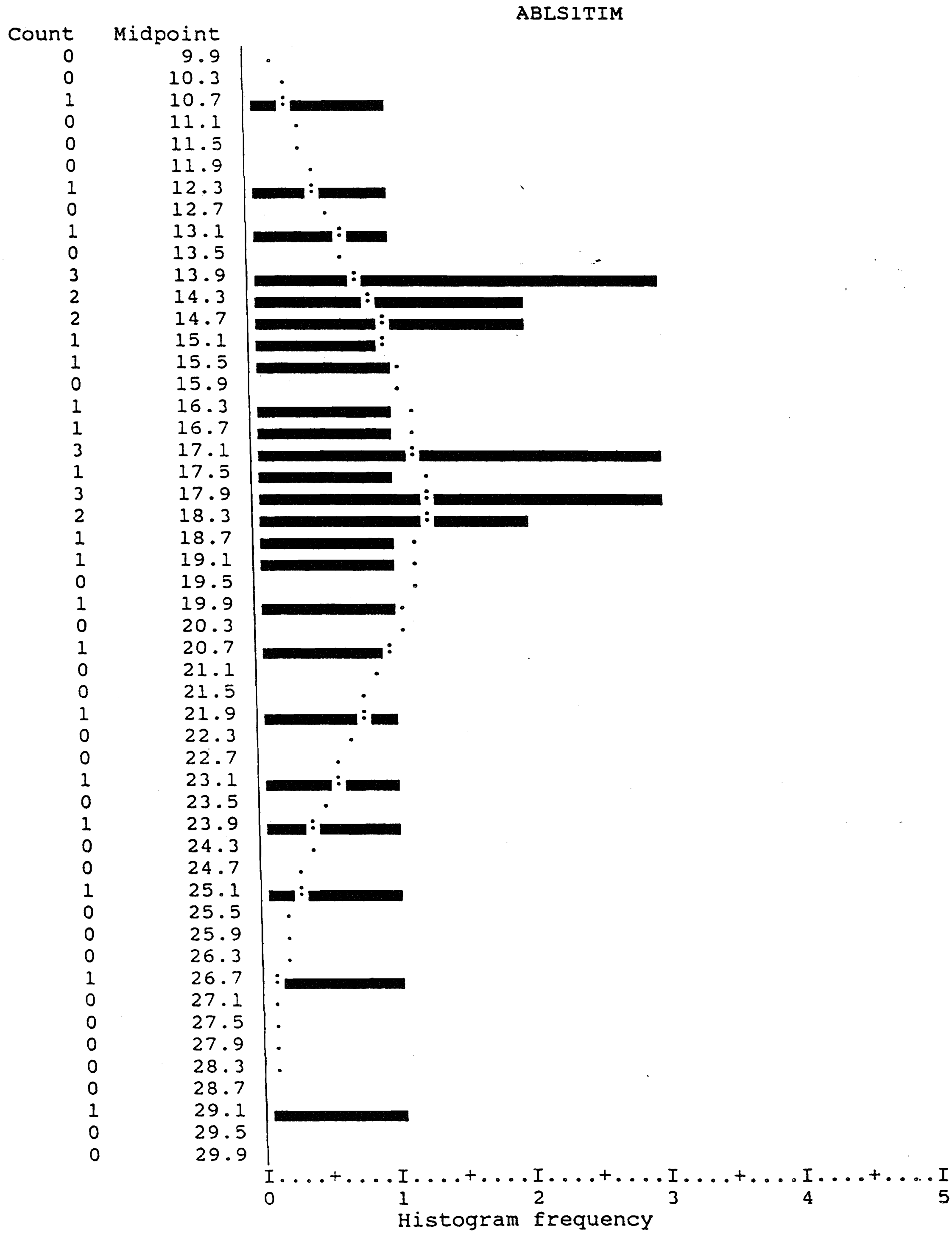


Figure 5

Mean response time in ms for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

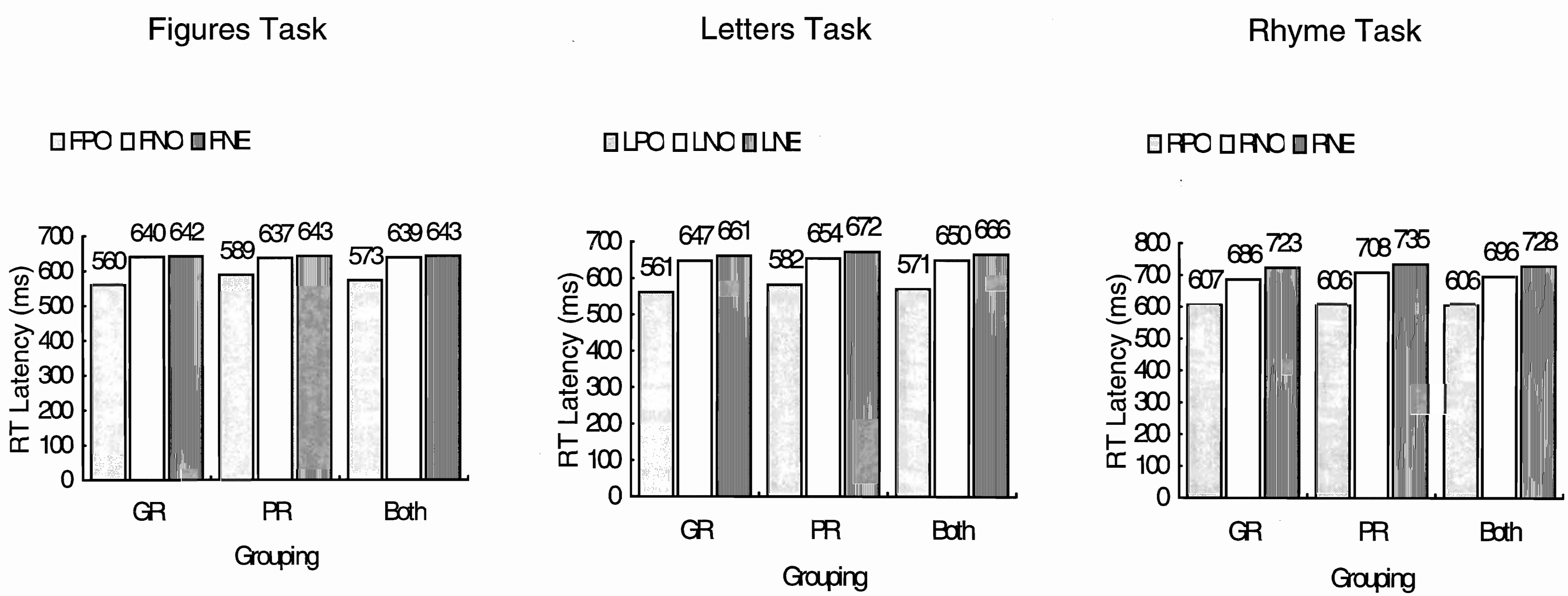


Figure 6

Response time negative and positive priming (the difference in response times between novel and positive or negative condition) in ms for good and poor readers.

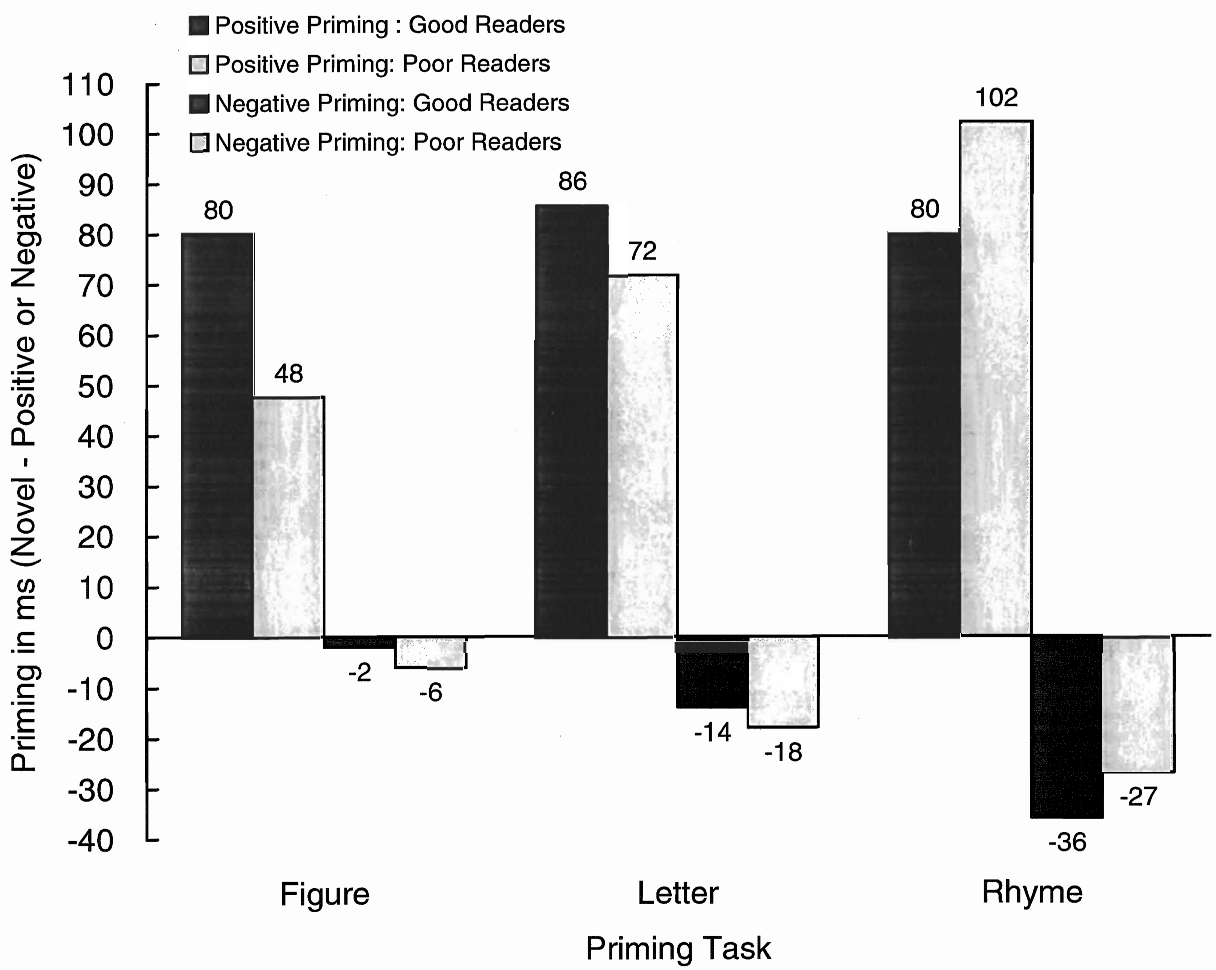


Figure 7

N1 latency at Cz in milliseconds for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

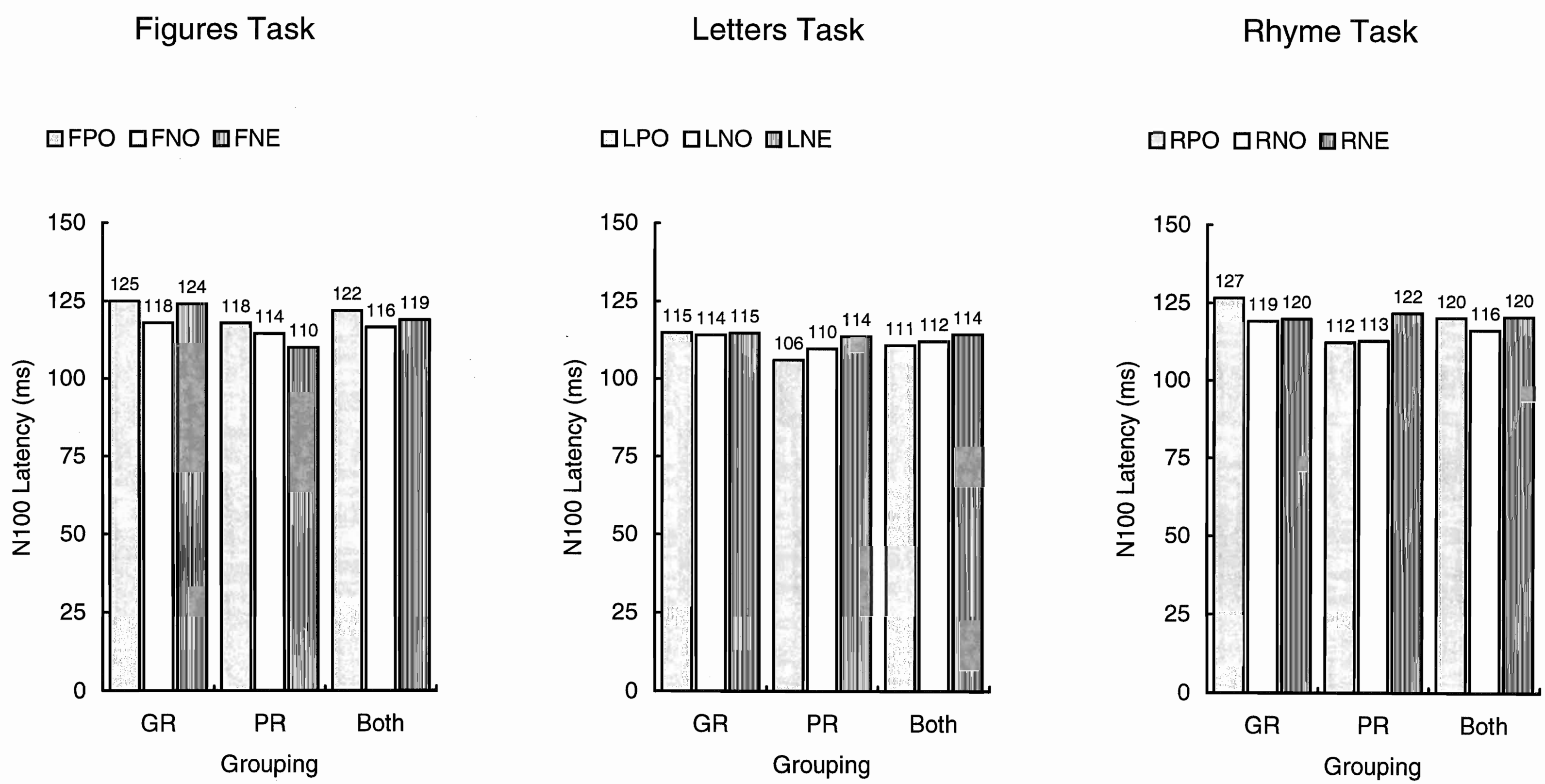


Figure 8

P2 latency at Cz in milliseconds for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

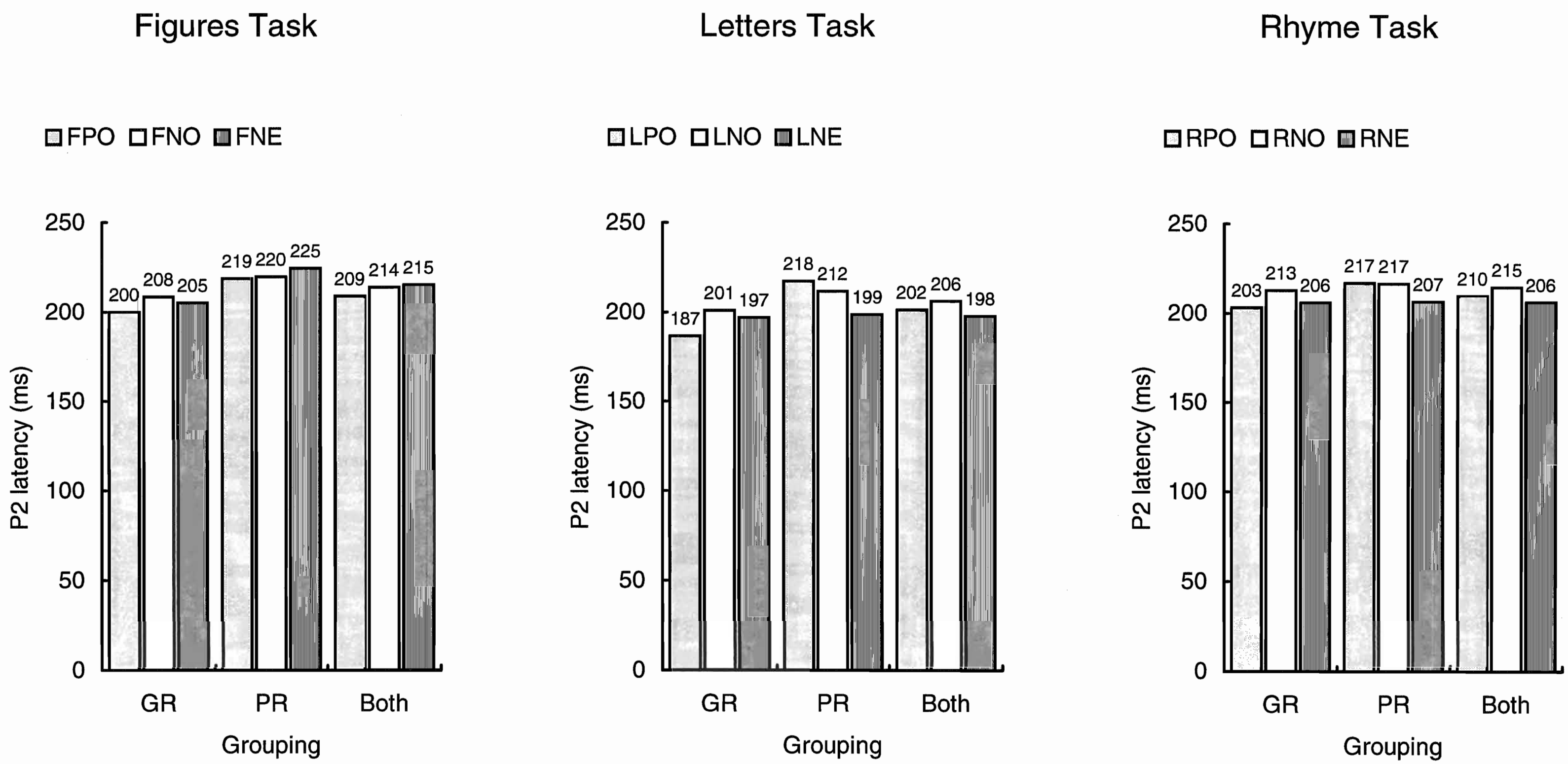


Figure 9

N2 latency at Cz in milliseconds for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

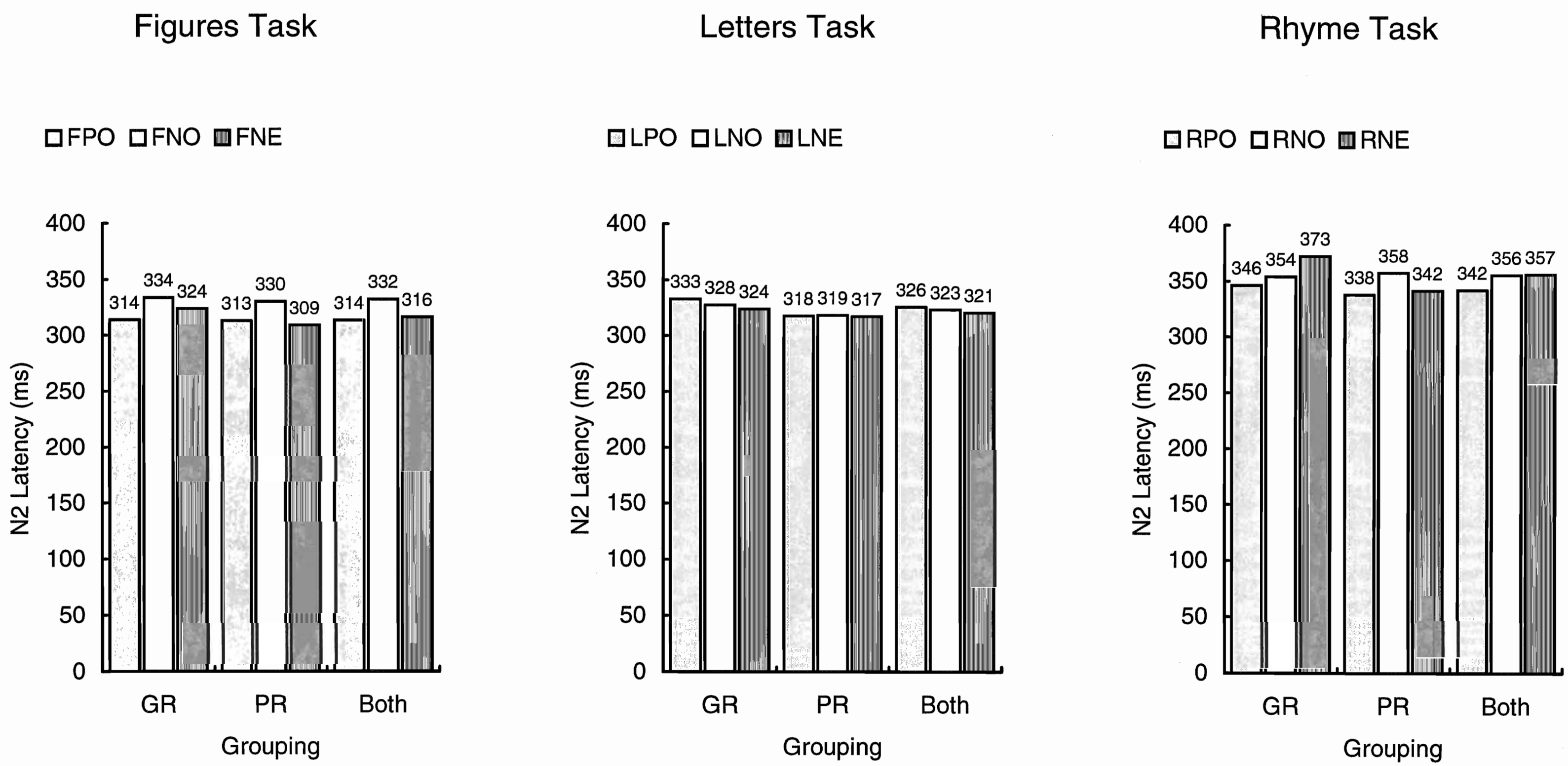


Figure 10

P3 latency at Pz in milliseconds for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

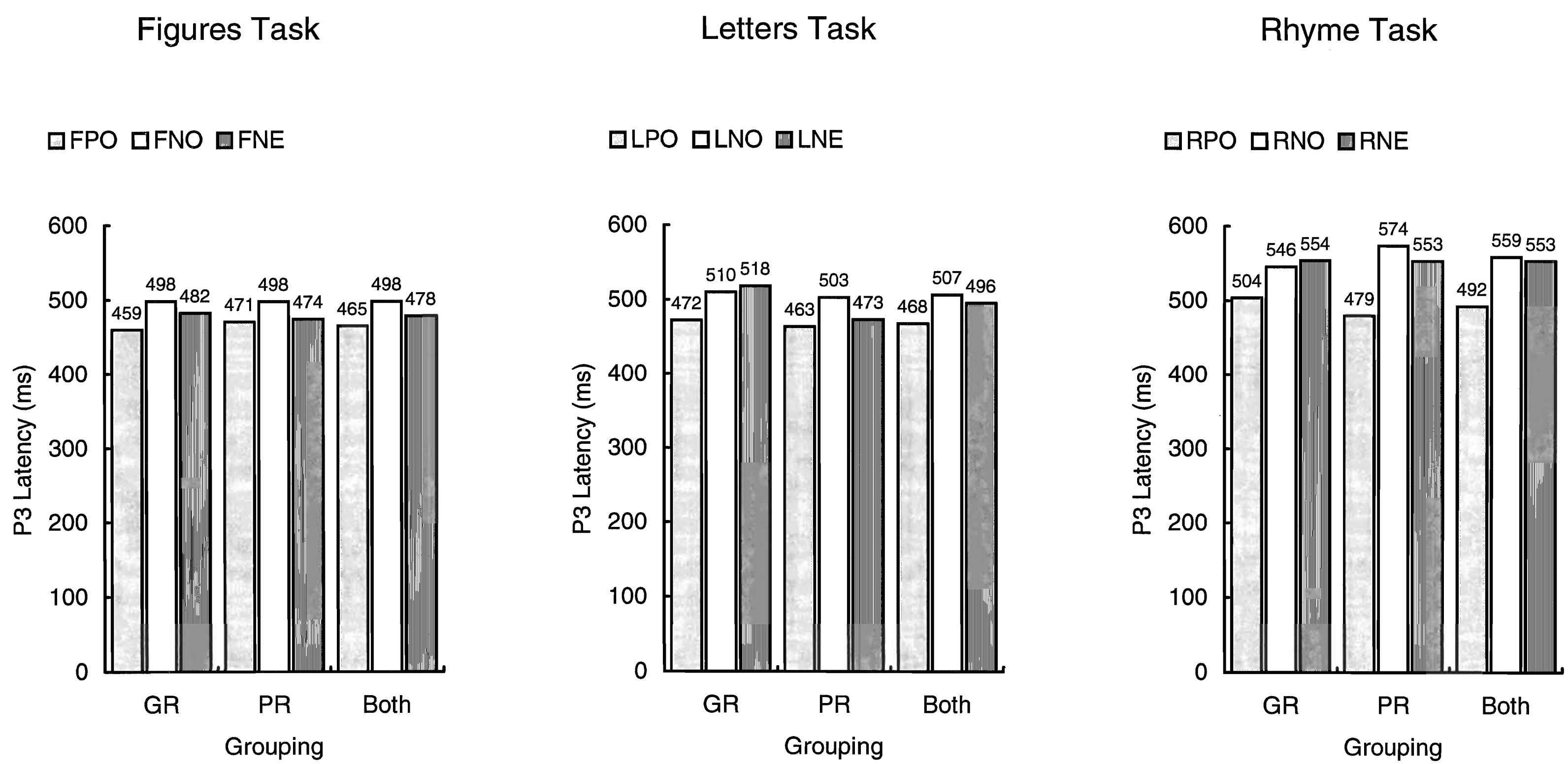


Figure 11

N1 amplitude at Cz in microvolts for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

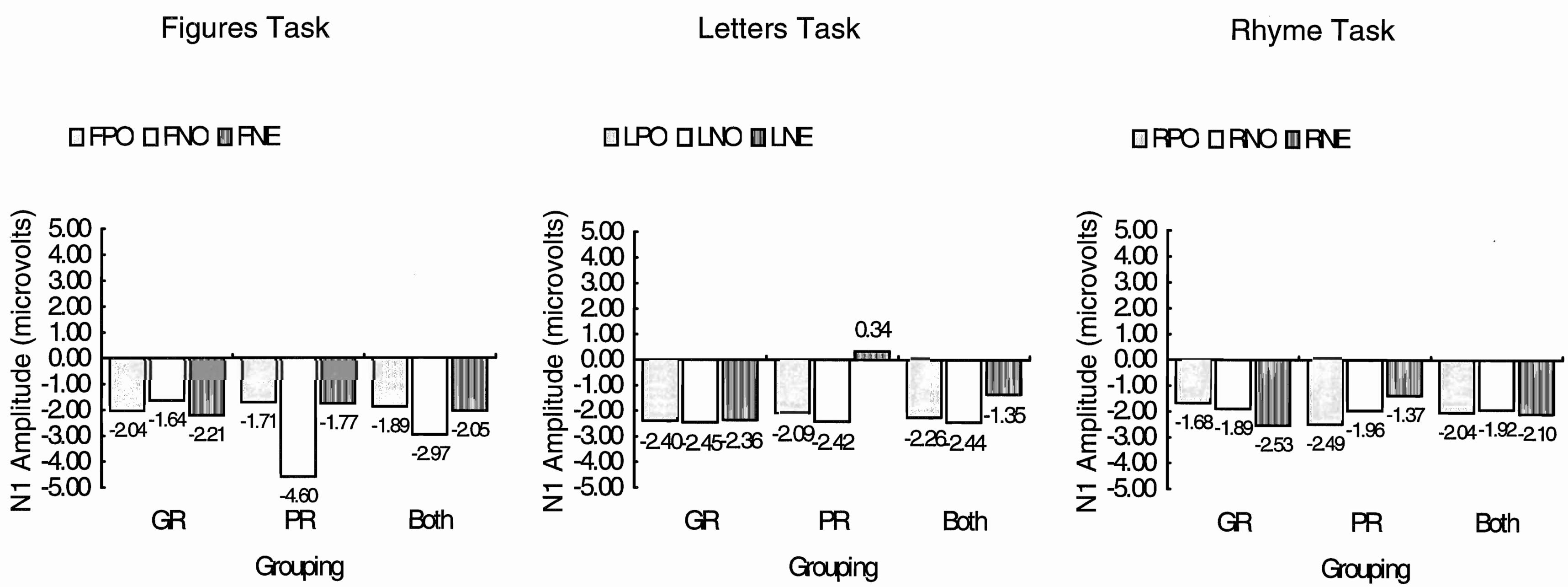


Figure 12

P2 amplitude at Cz in microvolts for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

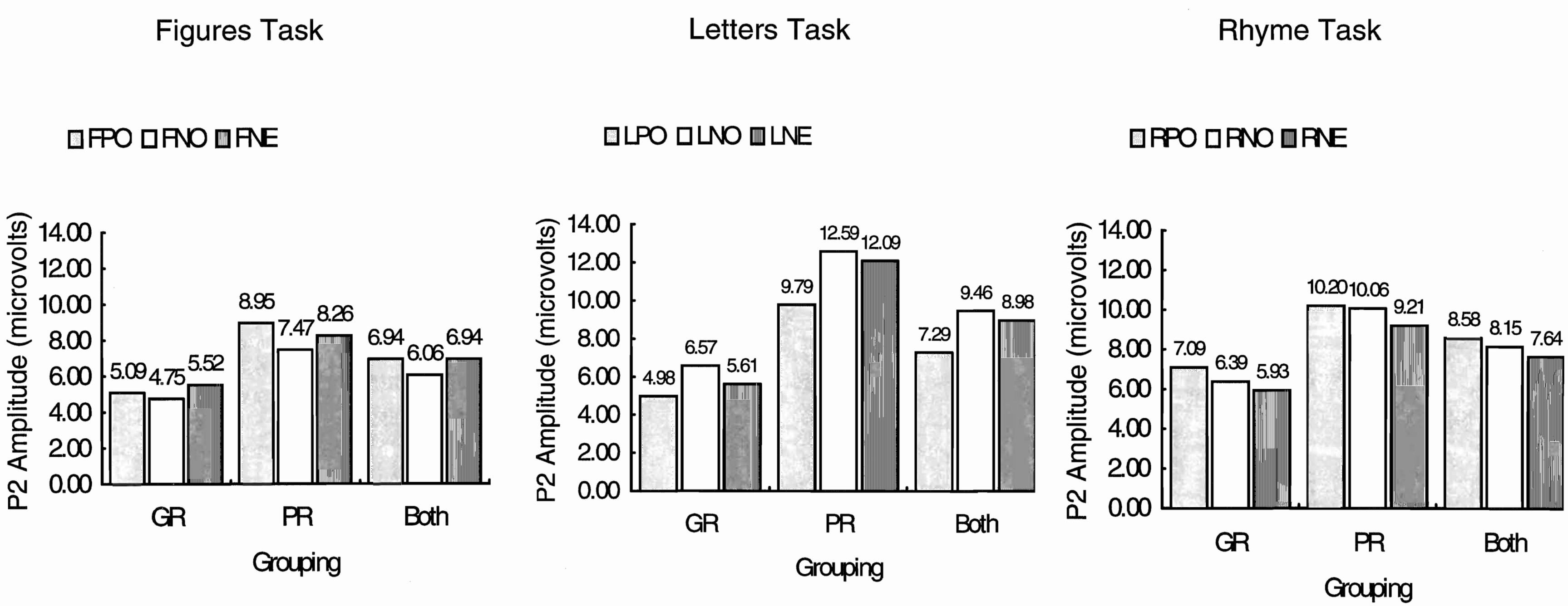


Figure 13

N2 amplitude at Cz in microvolts for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.

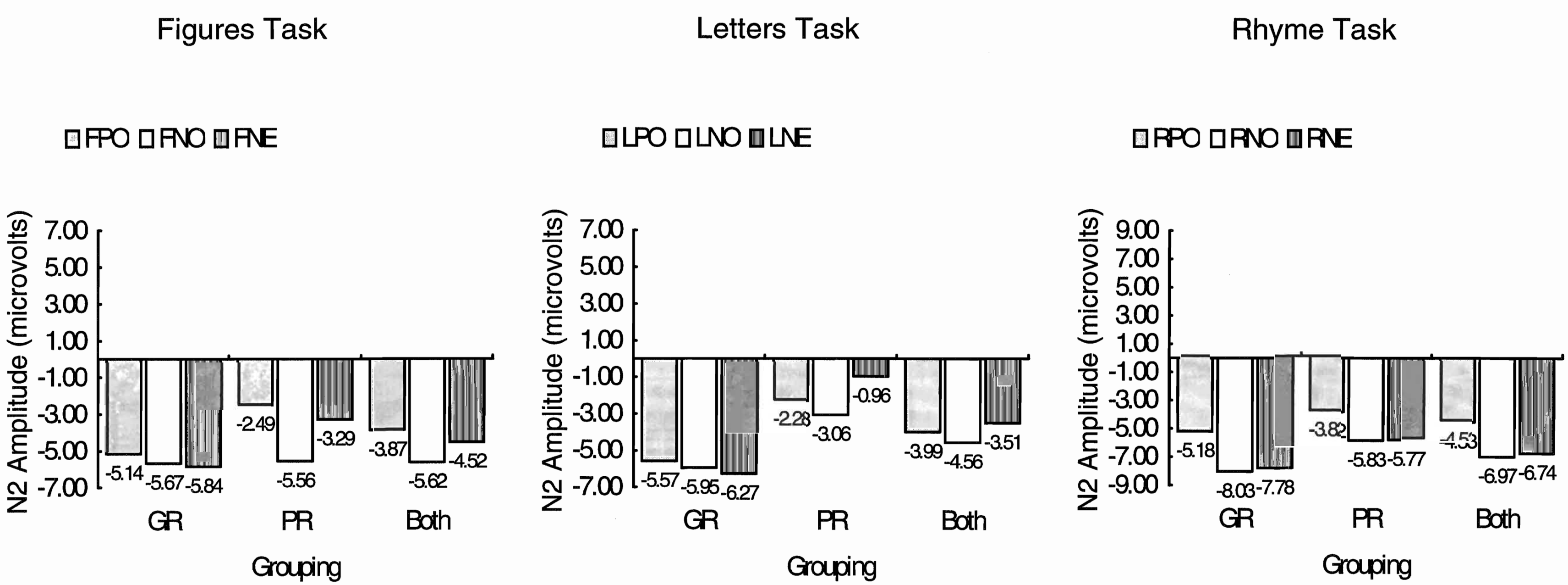
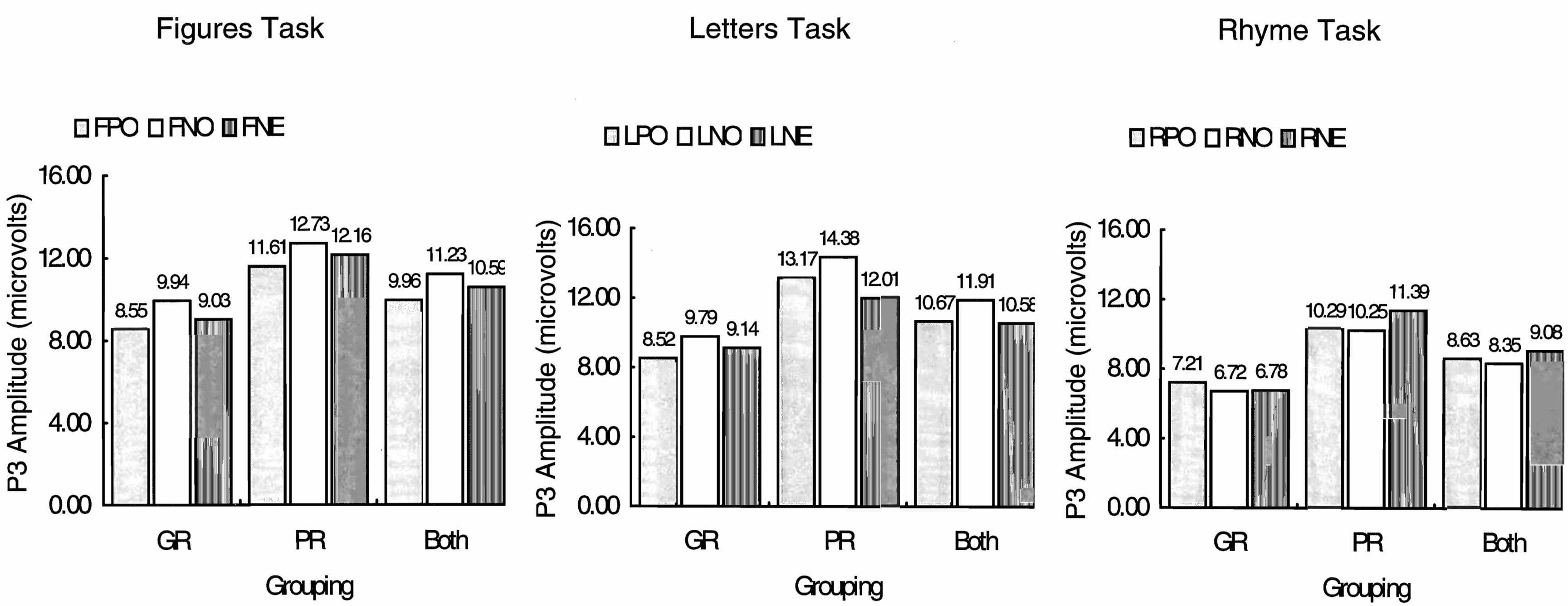


Figure 14

P3 amplitude at Pz in microvolts for Good Readers (GR) and Poor Readers (PR) across Figure (F), Letter (L), and Rhyme (R) tasks for the Positive (PO), Negative (NE), and Novel (NO) conditions.



Appendix

BROCK UNIVERSITY

Participant's Name: ______________________	ID (e.g. Ian Marsman = IAMA): ________
Seminar leader's name: ____________________	Participation time: ____________
Date/Time 1st: ____________________ 2nd ________________	
Tester: _________________________	

Health and History Questionnaire

First, I would like to get some general background information:

Age ________ Date of Birth (Year/Month/Day): ________________

Please circle the mark below that you feel corresponds to your handedness:

|__________|__________|__________|__________|

strong left ambidextrous strong right

Current living arrangements (with family? friends? alone?) ____________________

Currently employed? _______ Describe type of work/ hours/ duties, etc.
If not currently employed please describe last employment.

____

____

Education to date (e.g. high school, 1st year university, etc.) __________________

In general, how would you describe yourself as a student? (A B C) ____________________

Best subjects: _________________________ _________________________

Worst subjects: ________________________ _________________________

Have you ever failed a grade in school? __________ If so, please describe the circumstances.

____

Please list your major current and past hobbies.

____

____

BROCK UNIVERSITY

Now I would like to ask you some questions about your health. Have you had any.....

______ Serious childhood diseases?
______ Injuries, Falls, Broken bones?
______ Sports injuries?
______ High fevers?
______ Serious Infections?
______ Diabetes?
______ Liver problems?
______ Kidney problems?
______ Problems with arteries?
______ Stroke?
______ Seizures?
______ Hypertension?
______ Heart problems, Angina?
______ Blood problems?
______ Breathing problems?
______ Asthma, Emphysema?
______ Tuberculosis?
______ Skin disorders?
______ Serious allergies?
______ Cancer treatment?
______ Surgery?
______ Problems with vision?
______ Hearing problems?
______ Paralysis or Numbness?
______ Fainting or Dizziness?
______ Serious headaches?
______ Blurred vision?
______ Movement problems, Arthritis, Sore joints?

If yes to any of the above, please explain. When, how serious, long term effects? Nature of treatment (e.g. chemo therapy).

____

____

____

Have you ever had a blow to the head that caused you to stop what you were doing?: ______

If yes, at what age did this occur?: ________

Were you unconscious at all?: ________

How Long?: __________

Hospitalized?: ________

How Long?: __________

Are you taking any prescribed or over-the-counter medications? _________

Which ones? ______________________________

Purpose? ______________________________

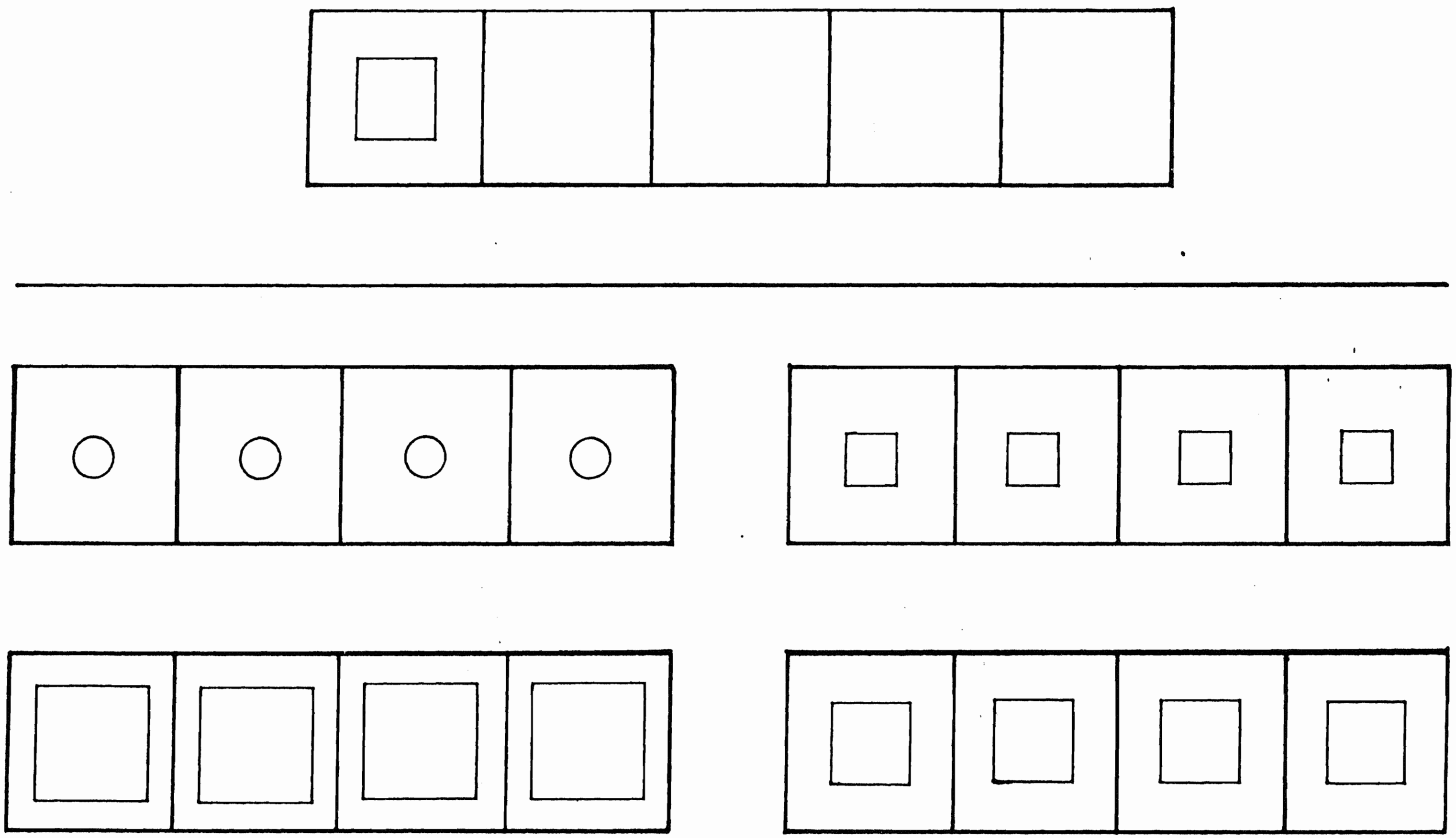
How would you describe your use of (none, mild, moderate, heavy):

Caffeine: ______________

Alchohol: ______________

Other stimulant drugs: ______________

Other relaxing drugs: ______________



Test of Non-Verbal Intelligence: This test requires participants to choose the item that completes the set containing spaces

Biemiller Reading Test

LETTERS

s c v h n r o i g y t r e w s f h c
n m o f q t m a d f g h m p k u h a
f d s a d g x v b y i b u i

STORY #1

One day a little brown bear and her father went out to play. They came to some water.

The little bear jumped into the water with a big splash. Then she splashed her father.

"This is fun! Come and play with me," said the little brown bear.

"No thank-you," said the father bear. "That water is too cold!"

The little brown bear saw a fish. She tried to catch it.

"Father, come and help me catch the fish!" called the little brown bear.

"I will come now," said the father bear. "It is never too cold to catch fish!"

Word List #1

bear thank catch now out said splash no bear water they fish I little play is jumped called big this you and come tried that down father the can to little day one are can into went for too with cold and it fun in a never here brown

STORY #2

John likes visiting the store near the lake. The store was full of food, clothes, and supplies for people who lived around the lake. There were also wood carvings and souvenirs for tourists. John was interested in all these things. But most of all, he liked the model canoe on the shelf next to the cash register. It was the nicest model he had ever seen.

Mr. Jones, who ran the store, saw John looking at the model canoe. "How do you like that model, John?" he asked.

"I like it very much!" answered John. "How much does it cost?"

Word List #2

was register visiting that looking answered full carvings there lake model how shelf cash were it nicest on every supplies around near in people he food asked interested saw had and things wood at who in seen cost does these store ran cans very tourists a lived much also

MOTIVATIONAL STATEMENT: Read this story to find out what Joe found.

"I see a goat!" said Joe.

"Hello, Goat!
How are you?
I see you.
I like you.
Be my goat."

"Dad will like you.
So will Mom.
Come with me."

"Dad! Dad!
Look! Look!
See my goat!
Can I keep him?
Can he stay in my room?
Please!"

"A goat?" asked Dad.
"No! No!
Not a goat!
Not in the house.
Goats are not clean."

[Note: Do not count as a miscue mispronunciation of the name Joe. You may pronounce this word for the student if needed.]

SCORING AID

WORD RECOGNITION

%	MISCUES
99	1
95	3
90	6
85	10

COMPREHENSION

%	ERRORS
100	0
87.5	1
75	2
62.5	3
50	4
37.5	5
25	6
12.5	7
0	8

64 WORDS

WPM

$\frac{3900}{\_\_\_}$

COMPREHENSION QUESTIONS

____ main idea	1. What would be a good title for this story? (Joe Finds a Goat; The Goat)
____ sequence	2. What was the first thing that happened in the story? (Joe saw a goat.)
____ detail	3. How did Joe feel about the goat he found? (He liked it.)
____ detail	4. How did Joe think Dad and Mom would feel about the goat? (They would like it.)
____ detail	5. Who did Joe call to see the goat? (Dad)
____ detail	6. Where did Joe want the goat to stay? (in his room)
____ inference	7. How did Dad feel about Joe keeping the goat in his room? (He didn't want him to.) What does the story say to make you believe that? (Dad says, "No! No!" and "Not in the house.")
____ cause and effect/ detail	8. Why didn't Dad want the goat in the house? (Goats are not clean.)

SCORING SHEET FOR COLOUR VISION ACCURACY TEST

BROWN	________	GREEN	________	BLACK	________
GREEN	________	BLACK	________	BLUE	________
RED	________	PURPLE	________	RED	________
BLUE	________	BROWN	________	ORANGE	________
PURPLE	________	ORANGE	________	BROWN	________
BLUE	________	RED	________	ORANGE	________
GREEN	________	PURPLE	________	BLACK	________
BLACK	________	BROWN	________	PURPLE	________
RED	________	PURPLE	________	RED	________
PURPLE	________	ORANGE	________	BLUE	________
ORANGE	________	BLACK	________	GREEN	________
BROWN	________	GREEN	________	PURPLE	________
BLACK	________	RED	________	BROWN	________

Form C Responses – Color Task

Stroop Task

1 BLUE______
2 GREEN______
3 TAN______
4 RED______
5 GREEN______
6 BLUE______
7 GREEN______
8 BLUE______
9 RED______
10 BLUE______
11 TAN______
12 RED______
13 TAN______
14 GREEN______
15 BLUE______
16 TAN______
17 GREEN______
18 RED______
19 TAN______
20 RED______
21 TAN______
22 RED______
23 GREEN______
24 RED______
25 TAN______
26 BLUE______
27 GREEN______
28 TAN______
29 RED______
30 GREEN______
31 TAN______
32 BLUE______
33 GREEN______
34 BLUE______
35 TAN______
36 GREEN______
37 TAN______
38 BLUE______
39 GREEN______
40 BLUE______
41 GREEN______
42 RED______
43 BLUE______
44 GREEN______
45 TAN______
46 RED______
47 TAN______
48 GREEN______
49 TAN______
50 RED______
51 BLUE______
52 RED______
53 GREEN______
54 RED______
55 TAN______
56 BLUE______
57 TAN______
58 RED______
59 TAN______
60 BLUE______
61 TAN______
62 RED______
63 GREEN______
64 RED______
65 BLUE______
66 TAN______
67 RED______
68 GREEN______
69 RED______
70 TAN______
71 BLUE______
72 TAN______
73 GREEN______
74 TAN______
75 BLUE______
76 TAN______
77 BLUE______
78 GREEN______
79 RED______
80 GREEN______
81 TAN______
82 RED______
83 GREEN______
84 BLUE______
85 RED______
86 TAN______
87 RED______
88 TAN______
89 BLUE______
90 GREEN______
91 RED______
92 BLUE______
93 RED______
94 TAN______
95 GREEN______
96 TAN______
97 BLUE______
98 RED______
99 BLUE______
100 RED______
101 GREEN______
102 RED______
103 BLUE______
104 TAN______
105 BLUE______
106 GREEN______
107 BLUE______
108 RED______
109 BLUE______
110 TAN______
111 BLUE______
112 GREEN______

Form C-W Responses – Color-Word Task

Stroop Task

1 RED ______	29 BLUE ______	57 BLUE ______	85 TAN ______
2 BLUE ______	30 TAN ______	58 TAN ______	86 RED ______
3 GREEN ______	31 GREEN ______	59 RED ______	87 GREEN ______
4 BLUE ______	32 RED ______	60 GREEN ______	88 BLUE ______
5 RED ______	33 BLUE ______	61 TAN ______	89 TAN ______
6 TAN ______	34 GREEN ______	62 RED ______	90 GREEN ______
7 BLUE ______	35 BLUE ______	63 GREEN ______	91 RED ______
8 RED ______	36 GREEN ______	64 BLUE ______	92 TAN ______
9 TAN ______	37 RED ______	65 GREEN ______	93 BLUE ______
10 GREEN ______	38 TAN ______	66 TAN ______	94 GREEN ______
11 BLUE ______	39 BLUE ______	67 BLUE ______	95 RED ______
12 RED ______	40 RED ______	68 GREEN ______	96 TAN ______
13 TAN ______	41 BLUE ______	69 RED ______	97 RED ______
14 BLUE ______	42 TAN ______	70 BLUE ______	98 GREEN ______
15 GREEN ______	43 RED ______	71 RED ______	99 RED ______
16 RED ______	44 TAN ______	72 GREEN ______	100 BLUE ______
17 TAN ______	45 BLUE ______	73 BLUE ______	101 RED ______
18 GREEN ______	46 RED ______	74 TAN ______	102 BLUE ______
19 BLUE ______	47 GREEN ______	75 GREEN ______	103 TAN ______
20 RED ______	48 BLUE ______	76 BLUE ______	104 GREEN ______
21 TAN ______	49 TAN ______	77 RED ______	105 RED ______
22 GREEN ______	50 GREEN ______	78 TAN ______	106 TAN ______
23 BLUE ______	51 RED ______	79 GREEN ______	107 BLUE ______
24 GREEN ______	52 TAN ______	80 RED ______	108 TAN ______
25 TAN ______	53 GREEN ______	81 TAN ______	109 RED ______
26 BLUE ______	54 TAN ______	82 BLUE ______	110 BLUE ______
27 TAN ______	55 BLUE ______	83 GREEN ______	111 GREEN ______
28 RED ______	56 RED ______	84 BLUE ______	112 TAN ______

RAW SCORE* ______

DIAGNOSTIC INTERPRETATION OF ERRORS:

IMPLICATIONS FOR INSTRUCTION:

*Assume that all items prior to the lowest administered item are correct. *Add* this number to the number of correct responses to obtain the Raw Score.

WORD ATTACK TEST

RAW SCORE ______

RESPONSES: (Incorrect responses may be recorded following the printed answers)

1 ____ ift	11 ____ ziz	21 ____ tob	31 ____ telequik
2 ____ bim	12 ____ olt	22 ____ chen	32 ____ shenning
3 ____ ut	13 ____ nudd	23 ____ hets	33 ____ quib
4 ____ rayed	14 ____ weet	24 ____ plon	34 ____ laip
5 ____ kak	15 ____ plen	25 ____ lundy	35 ____ tubwit
6 ____ maft	16 ____ twib	26 ____ hode	36 ____ pertome
7 ____ nen	17 ____ beb	27 ____ expram	37 ____ sloy
8 ____ ab	18 ____ rejune	28 ____ stabe	38 ____ subcrote
9 ____ tash	19 ____ knap	29 ____ imbaf	39 ____ pipped
10 ____ wip's	20 ____ ain	30 ____ eam	40 ____ elbom

41 ____ polybendable	46 ____ cigbet
42 ____ dinlan	47 ____ conration
43 ____ eldop	48 ____ biftel
44 ____ wubfambif	49 ____ bafmotbem
45 ____ wotfob	50 ____ nolhod

DIAGNOSTIC INTERPRETATION OF ERRORS:

IMPLICATIONS FOR INSTRUCTION:

Word/Nonword Task

From: Mitterer, J.O. (1980). There are two kinds of poor reader. Ph.D. Dissertation. McMaster University. Appendix 3, p. 163

SET A

WORDS		NONWORDS	
cute	boat	bule	bight
dime	bright	dook	cote
fine	cake	dure	dait
fool	coke	fike	frite
four	fail	gire	grean
fruit	feel	hine	hait
help	fight	boon	heer
huge	game	mook	heet
look	home	noor	hoal
mile	keep	puit	nale
moon	kite	rell	noat
most	mean	sith	rale
roof	seat	sive	sean
tire	toad	tish	sope
went	wait	wown	tite
will	white	wust	wright

SET B

WORDS		NONWORDS	
bite	book	belp	bote
coat	dive	bime	brite
date	down	bule	caik
fright	fire	cour	coak
green	fish	foon	fale
hate	like	gruit	feal
hear	line	fent	fite
heat	must	loof	gaim
hole	poor	nire	hoam
nail	rule	nost	keap
note	soon	nole	kight
rail	suit	pook	meen
seen	sure	puge	seet
soap	took	rine	tode
tight	well	sile	wate
write	with	vill	wight

Priming Task Instructions - LETTERS

Subject ID:_______LETP; _______LET (e.g. IAMALETP [for practice] & IAMALET).

In this task you will see two letters appear on the computer screen, one red and one blue. One of the letters will be above the other on the screen. Your task is to pay attention to the red letter and decide whether it contains an enclosed space or whether it is open. If the red letter does contain an enclosed space *(Show example closed letter given below)* you are to press the **F / J** key. If the red letter is open *(Show example open letter given below)* you are to press the **F / J** key. You are to ignore the blue letter. Please try to be as accurate as possible.

Closed Letter	**Open Letter**
p	K

Priming Task Instructions - SYMBOLS

Subject ID:______FIGP; ______FIG (e.g. IAMAFIGP [for practice] & IAMAFIG)

In this task you will see two symbols appear on the computer screen, one red and one blue. One of the symbols will be above the other on the screen. Your task is to pay attention to the red symbol and decide whether it contains an enclosed space or whether it is open. If the red symbol does contain an enclosed space *(Show example closed symbol given below)* you are to press the **F / J** key. If the red symbol is open *(Show example open symbol given below)* you are to press the **F / J** key. You are to ignore the blue symbol. Please try to be as accurate as possible.

Closed Symbol	**Open Symbol**
$\propto$	$\sum$

Priming Task Instructions - RHYME

Subject ID:_______LETP; _______LET (e.g. IAMALETP [for practice] & IAMALET)

In this task you will see two letters appear on the computer screen, one red and one blue. One of the letters will be above the other on the screen. Your task is to pay attention to the red letter and decide whether it rhymes with the sound "zee" or not. If the red letter does rhyme with the sound "zee" (*Show example rhyming letter given below)* you are to press the **F / J** key. If the red letter doesn't rhyme with "zee" (*Show example non-rhyme given below)* you are to press the **F / J** key. You are to ignore the blue letter. Please try to be as accurate as possible.

Rhyming Letter	**Non-rhyming Letter**
E	S

Stimuli Used in the Three Priming Tasks

Figures Task
Closed: ⌂ § ¶ α σ δ Θ Φ ∞ φ
Open: ─ >] ┤ ┴ ╒ π Γ μ ∩ ≡ τ ╫ ¬

Letters Task
Closed: a b d g o p q A B D O P Q R
Open: c f h j l n y C E F G H K U

Rhyme Task
Rhyme: A F L O Q R S X
Non Rhyme: B C D E G P T V

FIGURES TASK STIMULI
Note: first twelve trials are practice trials
Column data (in order):
- character "▓" does not print correctly here. On
  the computer screen it prints as "⌂".

```
Trial #
Prime Target T/B (1=Top, 0=Bottom)
Prime Target Lt/Rt (1=Left, 0=Right)
Probe Target T/B (1=Top, 0=Bottom)
Probe Target L/R (1=Left, 0=Right)
Prime Target (e.g. A or ╥)
Prime Ignore
Probe Target
Probe Ignore
Prime Target Open/Closed status
Prime Ignore O/C status
Probe Target O/C status
Probe Ignore O/C status
Probe Target Practice/Previous-Target/Previous-Ignore
      /Novel status (P, T, I, or N)

001 ,1,1,0,1,α,▓,α,Γ,c,c,c,o,P
002 ,1,0,0,0,§,∞,§,Θ,c,c,c,c,P
003 ,1,0,1,1,–,∞,δ,Φ,o,c,c,c,P
004 ,0,1,1,1,╫,▓,φ,δ,o,c,c,c,P
005 ,0,1,1,0,μ,α,¶,μ,o,c,c,o,P
006 ,0,0,0,1,¶,μ,μ,φ,c,o,o,c,P
007 ,0,1,1,0,▓,α,μ,§,c,c,o,c,P
008 ,1,1,0,1,▓,φ,▓,╥,c,c,c,o,P
009 ,0,0,1,0,δ,>,Φ,Θ,c,o,c,c,P
010 ,0,0,1,0,Φ,╒,╒,≡,c,o,o,o,P
011 ,0,0,1,0,μ,α,μ,╒,o,c,o,o,P
012 ,0,0,1,1,Θ,>,Θ,δ,c,o,c,c,P
1  ,1,0,0,1,∩,>,∩,Φ,o,o,o,c,T
2  ,0,1,0,0,¬,≡,≡,∞,o,o,o,c,I
3  ,1,0,1,0,╫,φ,╫,σ,o,c,o,c,T
4  ,1,1,1,1,σ,▓,α,Φ,c,c,c,c,N
5  ,0,0,0,1,δ,¶,μ,Θ,c,c,o,c,N
6  ,0,0,1,0,μ,],],┤,o,o,o,o,I
7  ,1,1,0,1,α,▓,α,Γ,c,c,c,o,T
8  ,0,0,1,0,┤,∞,┤,╫,o,c,o,o,T
9  ,0,1,1,0,φ,┴,┴,–,c,o,o,o,I
10,1,0,1,1,Θ,Φ,Φ,¶,c,c,c,c,I
11,1,1,0,0,≡,δ,α,],o,c,c,o,N
12,1,0,1,1,▓,┤,▓,φ,c,o,c,c,T
13,0,0,0,0,Γ,δ,Γ,╥,o,c,o,o,T
14,1,1,0,1,>,σ,σ,∞,o,c,c,c,I
15,0,1,0,1,¶,╫,¶,§,c,o,c,c,T
16,1,0,1,0,τ,¬,∩,┴,o,o,o,o,N
17,0,1,0,1,–,μ,μ,≡,o,o,o,o,I
18,1,1,1,0,Γ,α,α,φ,o,c,c,c,I
```

19,1,0,0,0,§,∞,§,Θ,c,c,c,c,T
20,0,0,1,1,μ,╥,∞,¶,o,o,c,c,N
21,1,1,0,0,▒,Γ,Γ,Θ,c,o,o,c,I
22,1,0,0,1,],Φ,Φ,∞,o,c,c,c,I
23,0,1,1,1,ϕ,§,ϕ,╥,c,c,c,o,T
24,0,1,0,0,α,┴,μ,▒,c,o,o,c,N
25,1,0,1,1,−,∞,δ,Φ,o,c,c,c,N
26,0,1,1,0,ϕ,Φ,ϕ,¬,c,c,c,o,T
27,1,0,0,1,δ,α,τ,▒,o,c,c,o,N
28,0,0,0,1,╥,∩,ϕ,¶,o,o,c,c,N
29,1,0,1,0,>,Θ,Θ,Γ,o,c,c,o,I
30,1,1,0,0,Φ,σ,Φ,τ,c,c,c,o,T
31,0,1,1,1,╫,▒,ϕ,δ,o,c,c,c,N
32,0,1,0,0,α,−,−,¶,c,o,o,c,I
33,1,0,1,1,∩,μ,∩,α,o,o,o,c,T
34,0,0,1,0,σ,§,§,∞,c,c,c,c,I
35,0,1,0,1,Θ,μ,],Φ,c,o,o,c,N
36,1,1,1,0,Γ,▒,Γ,σ,o,c,o,c,T
37,0,0,0,0,α,¬,α,§,c,o,c,c,T
38,1,1,0,1,−,┤,∞,Θ,o,o,c,c,N
39,0,0,1,1,Φ,┴,┴,Φ,c,o,o,c,I
40,0,1,1,0,μ,α,¶,μ,o,c,c,o,N
41,0,1,1,0,▒,ϕ,▒,σ,c,c,c,c,T
42,1,0,0,1,>,≡,>,¬,o,o,o,o,T
43,1,0,1,0,∞,∩,∩,δ,c,o,o,c,I
44,0,1,1,1,§,▒,∞,Φ,c,c,c,c,N
45,1,0,0,1,≡,┤,¶,╫,o,o,c,o,N
46,0,1,1,0,],Γ,],−,o,o,o,o,T
47,0,1,0,0,α,╥,μ,§,c,o,o,c,N
48,1,0,1,1,μ,δ,δ,≡,o,c,c,o,I
49,0,0,0,1,¶,μ,μ,ϕ,c,o,o,c,I
50,1,0,0,0,▒,┴,−,╫,c,o,o,o,N
51,0,1,1,1,α,∞,α,¬,c,c,c,o,T
52,1,1,1,0,τ,§,▒,σ,o,c,c,c,N
53,1,0,0,1,¶,Θ,¶,Φ,c,c,c,c,T
54,▒,1,1,1,╥,ϕ,ϕ,┴,o,c,c,o,I
55,1,0,0,0,δ,α,−,μ,c,c,o,o,N
56,0,1,1,0,σ,Γ,Γ,¶,c,o,o,c,I
57,1,1,1,1,┤,╫,┤,▒,o,o,o,c,T
58,1,1,0,1,Θ,┴,Θ,╥,c,o,c,o,T
59,1,0,1,0,δ,μ,μ,¬,c,o,o,o,I
60,0,0,0,1,−,Φ,−,σ,o,c,o,c,T
61,0,1,1,0,▒,α,μ,§,c,c,o,c,N
62,1,0,0,1,ϕ,╥,ϕ,Θ,c,o,c,c,T
63,1,1,0,1,∞,],∩,Φ,c,o,o,c,N
64,0,1,1,0,Γ,μ,μ,┤,o,o,o,o,I
65,0,0,1,0,δ,Φ,−,▒,c,c,o,c,N
66,1,0,0,1,∩,σ,∩,╥,o,c,o,o,T
67,1,1,1,0,╫,ϕ,╫,∞,o,c,o,c,T
68,0,1,0,1,§,▒,Φ,α,c,c,c,c,N
69,1,0,1,0,≡,¶,¶,┴,o,c,c,o,I
70,1,1,1,0,μ,>,μ,Γ,o,o,o,o,T

71,0,0,0,1,§,Θ,μ,τ,c,c,o,o,N
72,1,1,0,1,],Φ,Φ,▒,o,c,c,c,I
73,0,1,1,0,¶,δ,δ,∞,c,c,c,c,I
74,1,0,0,1,╥,α,╥,§,o,c,o,c,T
75,0,0,1,0,φ,▒,≡,μ,c,c,o,o,N
76,1,1,0,0,§,],],τ,c,o,o,o,I
77,1,0,1,1,┴,Γ,┴,μ,o,o,o,o,T
78,0,1,0,0,>,σ,Φ,∩,o,c,c,o,N
79,0,0,1,1,α,−,−,╫,c,o,o,o,I
80,1,0,0,0,¬,δ,δ,Γ,o,c,c,o,I
81,1,1,0,1,▒,φ,▒,╥,c,c,c,o,T
82,0,0,1,0,τ,∞,∞,σ,o,c,c,c,I
83,1,0,0,1,¶,§,¶,∩,c,c,c,o,T
84,0,1,1,0,Θ,μ,τ,Φ,c,o,o,o,N
85,1,0,1,1,┴,≡,δ,¬,o,o,c,o,N
86,1,1,0,0,α,∩,∩,−,c,o,o,o,I
87,0,1,1,0,┤,╥,┤,¬,o,o,o,o,T
88,0,0,0,1,¶,μ,¶,>,c,o,c,o,T
89,0,1,0,0,−,┤,φ,▒,o,o,c,c,N
90,0,0,1,1,≡,μ,μ,∩,o,o,o,o,I
91,1,1,0,1,σ,α,σ,τ,c,c,c,o,T
92,0,0,1,0,δ,>,Φ,Θ,c,o,c,c,N
93,1,1,0,1,Γ,−,−,┤,o,o,o,o,I
94,0,1,0,0,α,╫,α,φ,c,o,c,c,T
95,0,0,1,1,┴,≡,∞,>,o,o,c,o,N
96,1,1,1,0,Φ,¬,Θ,μ,c,o,c,o,N
97,1,0,0,0,¶,μ,¶,Γ,c,o,c,o,T
98,0,1,1,1,∞,┤,σ,>,c,o,c,o,N
99,1,0,0,1,∩,α,α,▒,o,c,c,c,I
100,0,0,1,0,Φ,┴,┴,≡,c,o,o,o,I
101,1,1,0,1,¬,∩,¬,▒,o,o,o,c,T
102,1,1,0,0,¶,§,§,>,c,c,c,o,I
103,0,0,1,1,φ,┤,╥,Γ,c,o,o,o,N
104,1,1,0,0,≡,╫,≡,],o,o,o,o,T
105,0,0,1,1,Φ,μ,μ,τ,c,o,o,o,I
106,1,1,0,1,τ,¬,¬,¶,o,o,o,c,I
107,0,0,1,0,μ,α,μ,┴,o,c,o,o,T
108,0,1,1,1,δ,σ,▒,φ,c,c,c,c,N
109,1,0,0,0,],¶,¶,┤,o,c,c,o,I
110,1,0,1,1,┴,∞,┴,Θ,o,c,o,c,T
111,0,1,0,0,>,μ,φ,╫,o,o,c,o,N
112,1,0,0,0,α,▒,§,Φ,c,c,c,c,N
113,0,1,1,1,∞,τ,τ,¬,c,o,o,o,I
114,0,1,0,0,╥,Θ,╥,≡,o,c,o,o,T
115,1,0,1,1,╫,┴,α,−,o,o,c,o,N
116,0,0,0,0,μ,Φ,Φ,],o,c,c,o,I
117,0,0,1,1,Θ,>,Θ,δ,c,o,c,c,T
118,1,1,1,1,≡,Γ,α,┴,o,o,c,o,N
119,1,0,0,0,▒,§,§,▒,c,c,c,c,I
120,0,1,1,0,¬,φ,φ,α,o,c,c,c,I

LETTERS TASK STIMULI
Note: first twelve trials are practice trials

Column data (in order):

Trial #
Prime Target T/B (1=Top, 0=Bottom)
Prime Target Lt/Rt (1=Left, 0=Right)
Probe Target T/B (1=Top, 0=Bottom)
Probe Target L/R (1=Left, 0=Right)
Prime Target (e.g. A or q)
Prime Ignore
Probe Target
Probe Ignore
Prime Target Open/Closed status
Prime Ignore O/C status
Probe Target O/C status
Probe Ignore O/C status
Probe Target Practice/Previous-Target/Previous-Ignore
/Novel status (P, T, I, or N)

```
001 ,1,1,0,1,b,O,b,j,c,c,c,o,P
002 ,1,0,0,0,q,R,q,D,c,c,c,c,P
003 ,0,1,1,1,H,o,a,Q,o,c,c,c,P
004 ,0,0,0,0,g,C,g,q,c,o,c,c,P
005 ,0,0,0,1,P,h,h,a,c,o,o,c,P
006 ,0,1,1,0,o,b,U,q,c,c,o,c,P
007 ,1,1,0,1,D,a,D,y,c,c,c,o,P
008 ,0,0,1,0,Q,G,O,A,c,o,c,c,P
009 ,0,0,1,0,g,E,E,K,c,o,o,o,P
010 ,0,0,1,0,h,B,h,E,o,c,o,o,P
011 ,0,0,1,1,A,G,A,Q,c,o,c,c,P
012 ,0,0,1,0,F,R,R,B,o,c,c,c,P
1  ,1,0,0,1,n,G,n,p,o,o,o,c,T
2  ,0,1,0,0,C,K,K,R,o,o,o,c,I
3  ,1,0,1,0,H,a,H,d,o,c,o,c,T
4  ,1,1,1,1,d,o,b,g,c,c,c,c,N
5  ,0,0,0,1,Q,P,U,A,c,c,o,c,N
6  ,0,0,1,0,U,c,c,f,o,o,o,o,I
7  ,1,1,0,1,b,O,b,j,c,c,c,o,T
8  ,0,0,1,0,f,R,f,H,o,c,o,o,T
9  ,0,1,1,0,g,E,E,l,c,o,o,o,I
10,1,0,1,1,A,D,D,P,c,c,c,c,I
11,1,1,0,0,K,Q,b,c,o,c,c,o,N
12,1,0,1,1,o,f,o,a,c,o,c,c,T
13,0,0,0,0,j,Q,j,y,o,c,o,o,T
14,1,1,0,1,G,d,d,B,o,c,c,c,I
15,0,1,0,1,P,H,P,q,c,o,c,c,T
16,1,0,1,0,F,C,n,E,o,o,o,o,N
17,0,1,0,1,l,U,U,K,o,o,o,o,I
18,1,1,1,0,j,g,g,a,o,c,c,c,I
```

19,1,0,0,0,q,R,q,D,c,c,c,c,T
20,0,0,1,1,h,y,R,P,o,o,c,c,N
21,1,1,0,0,O,j,j,A,c,o,o,c,I
22,1,0,0,1,c,p,p,R,o,c,c,c,I
23,0,1,1,1,D,q,D,y,c,c,c,o,T
24,0,1,0,0,B,E,U,g,c,o,o,c,N
25,1,0,1,1,l,R,Q,O,o,c,c,c,N
26,0,1,1,0,a,D,a,C,c,c,c,o,T
27,1,0,0,1,Q,B,F,o,o,c,c,o,N
28,0,0,0,1,y,n,D,P,o,o,c,c,N
29,1,0,1,0,G,A,A,j,o,c,c,o,I
30,1,1,0,0,p,d,p,F,c,c,c,o,T
31,0,1,1,1,H,o,a,Q,o,c,c,c,N
32,0,1,0,0,b,l,l,P,c,o,o,c,I
33,1,0,1,1,n,U,n,b,o,o,o,c,T
34,0,0,1,0,d,q,q,R,c,c,c,c,I
35,0,1,0,1,A,h,c,p,c,o,o,c,N
36,1,1,1,0,j,O,j,B,o,c,o,c,T
37,0,0,0,0,g,C,g,q,c,o,c,c,T
38,1,1,0,1,l,f,R,D,o,o,c,c,N
39,0,0,1,1,O,E,E,Q,c,o,o,c,I
40,0,1,1,0,U,b,P,h,o,c,c,o,N
41,0,1,1,0,o,a,o,d,c,c,c,c,T
42,1,0,0,1,G,K,G,C,o,o,o,o,T
43,1,0,1,0,R,n,n,B,c,o,o,c,I
44,0,1,1,1,q,o,g,D,c,c,c,c,N
45,1,0,0,1,K,f,P,H,o,o,c,o,N
46,0,1,1,0,c,j,c,l,o,o,o,o,T
47,0,1,0,0,D,y,U,O,c,o,o,c,N
48,1,0,1,1,h,Q,Q,K,o,c,c,o,I
49,0,0,0,1,P,h,h,a,c,o,o,c,I
50,1,0,0,0,D,E,l,H,c,o,o,o,N
51,0,1,1,1,B,R,B,C,c,c,c,o,T
52,1,1,1,0,F,q,o,d,o,c,c,c,N
53,1,0,0,1,P,A,P,g,c,c,c,c,T
54,o,1,1,1,y,O,O,E,o,c,c,o,I
55,1,0,0,0,Q,B,l,U,c,c,o,o,N
56,0,1,1,0,d,j,j,P,c,o,o,c,I
57,1,1,1,1,f,H,f,o,o,o,o,c,T
58,1,1,0,1,A,E,A,y,c,o,c,o,T
59,1,0,1,0,Q,h,h,C,c,o,o,o,I
60,0,0,0,1,l,p,l,d,o,c,o,c,T
61,0,1,1,0,o,b,U,q,c,c,o,c,N
62,1,0,0,1,g,y,g,A,c,o,c,c,T
63,1,1,0,1,R,c,n,p,c,o,o,c,N
64,0,1,1,0,j,h,h,f,o,o,o,o,I
65,0,0,1,0,Q,l,O,c,c,c,o,c,N
66,1,0,0,1,n,d,n,y,o,c,o,o,T
67,1,1,1,0,H,a,H,R,o,c,o,c,T
68,0,1,0,1,D,o,b,b,c,c,c,c,N
69,1,0,1,0,K,P,P,E,o,c,c,o,I

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70,1,1,1,0,U,G,U,j,o,o,o,o,T
71,0,0,0,1,q,A,h,F,c,c,o,o,N
72,1,1,0,1,c,O,O,g,o,c,c,c,I
73,0,1,1,0,P,B,B,R,c,c,c,c,I
74,1,0,0,1,y,D,y,q,o,c,o,c,T
75,0,0,1,0,a,g,K,U,c,c,o,o,N
76,1,1,0,0,O,c,c,F,c,o,o,o,I
77,1,0,1,1,E,j,E,h,o,o,o,o,T
78,0,1,0,0,G,d,p,n,o,c,c,o,N
79,0,0,1,1,b,l,l,H,c,o,o,o,I
80,1,0,0,0,C,Q,Q,j,o,c,c,o,I
81,1,1,0,1,D,a,D,y,c,c,c,o,T
82,0,0,1,0,F,R,R,B,o,c,c,c,I
83,1,0,0,1,P,D,P,n,c,c,c,o,T
84,0,1,1,0,A,U,F,C,c,o,o,o,N
85,1,0,1,1,E,K,Q,C,o,o,c,o,N
86,1,1,0,0,g,n,n,l,c,o,o,o,I
87,0,1,1,0,f,y,f,C,o,o,o,o,T
88,0,0,0,1,B,h,B,G,c,o,c,o,T
89,0,1,0,0,l,f,a,o,o,o,c,c,N
90,0,0,1,1,h,U,U,n,o,o,o,o,I
91,1,1,0,1,d,b,d,F,c,c,c,o,T
92,0,0,1,0,Q,G,O,A,c,o,c,c,N
93,1,1,0,1,j,l,l,f,o,o,o,o,I
94,0,1,0,0,b,H,b,D,c,o,c,c,T
95,0,0,1,1,E,K,R,G,o,o,c,o,N
96,1,1,1,0,O,C,A,h,c,o,c,o,N
97,1,0,0,0,P,U,P,j,c,o,c,o,T
98,0,1,1,1,R,F,d,G,c,o,c,o,N
99,1,0,0,1,n,b,b,D,o,c,c,c,I
100,0,0,1,0,g,E,E,K,c,o,o,o,I
101,1,1,0,1,C,n,C,o,o,o,o,c,T
102,1,1,0,0,P,q,q,G,c,c,c,o,I
103,0,0,1,1,a,f,y,j,c,o,o,o,N
104,1,1,0,0,K,H,K,c,o,o,o,o,T
105,0,0,1,1,O,U,U,F,c,o,o,o,I
106,1,1,0,1,F,C,C,P,o,o,o,c,I
107,0,0,1,0,h,B,h,E,o,c,o,o,T
108,0,1,1,1,Q,d,O,a,c,c,c,c,N
109,1,0,0,0,c,P,P,f,o,c,c,o,I
110,1,0,1,1,E,R,E,B,o,c,o,c,T
111,0,1,0,0,G,U,O,H,o,o,c,o,N
112,1,0,0,0,b,D,q,p,c,c,c,c,N
113,0,1,1,1,R,F,F,C,c,o,o,o,I
114,0,1,0,0,y,A,y,K,o,c,o,o,T
115,1,0,1,1,H,E,b,l,o,o,c,o,N
116,0,0,0,0,U,p,p,c,o,c,c,o,I
117,0,0,1,1,A,G,A,Q,c,o,c,c,T
118,1,1,1,1,K,j,b,E,o,o,c,o,N
119,1,0,0,0,D,q,q,o,c,c,c,c,I
120,0,1,1,0,C,a,a,g,o,c,c,c,I
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RHYME TASK STIMULI
Note: first twelve trials are practice trials

Column data (in order):

Trial #
Prime Target T/B (1=Top, 0=Bottom)
Prime Target Lt/Rt (1=Left, 0=Right)
Probe Target T/B (1=Top, 0=Bottom)
Probe Target L/R (1=Left, 0=Right)
Prime Target (e.g. A or C)
Prime Ignore
Probe Target
Probe Ignore
Prime Target non-rhyme/rhyme status
Prime Ignore n/r status
Probe Target n/r status
Probe Ignore n/r status
Probe Target Practice/Previous-Target/Previous-Ignore
/Novel status (P, T, I, or N)

```
001 ,0,1,0,0,Q,X,X,V,n,n,n,r,P
002 ,0,1,0,1,L,S,S,X,n,n,n,n,P
003 ,1,0,0,1,E,F,B,C,n,r,r,n,P
004 ,0,1,1,0,S,B,P,A,n,r,r,n,P
005 ,1,0,0,0,E,B,L,S,r,r,n,n,P
006 ,0,0,1,0,B,L,E,C,r,r,n,r,P
007 ,0,0,1,0,T,E,X,S,r,r,n,n,P
008 ,1,0,1,1,S,X,Q,A,n,n,r,n,P
009 ,0,0,1,1,Q,X,V,R,n,n,r,n,P
010 ,0,0,1,1,C,S,S,F,r,n,n,n,P
011 ,1,0,0,0,G,D,L,P,r,r,r,r,P
012 ,0,1,1,0,O,T,T,E,n,r,r,r,P
1  ,1,0,0,1,R,L,R,P,n,n,n,r,T
2  ,0,1,0,0,Q,X,X,V,n,n,n,r,I
3  ,1,0,1,0,A,T,A,G,n,r,n,r,T
4  ,1,1,1,1,D,C,B,V,r,r,r,r,N
5  ,0,0,0,1,E,P,S,T,r,r,n,r,N
6  ,0,0,1,0,S,O,O,F,n,n,n,n,I
7  ,1,1,0,1,X,C,B,S,r,r,r,n,T
8  ,0,0,1,0,F,V,F,A,n,r,n,n,T
9  ,0,1,1,0,E,Q,Q,L,r,n,n,n,I
10 ,1,0,1,1,T,D,D,P,r,r,r,r,I
11 ,1,1,0,0,X,E,B,O,n,r,r,n,N
12 ,1,0,1,1,C,F,C,T,r,n,r,r,T
13 ,0,0,0,0,S,V,S,R,n,r,n,n,T
14 ,1,1,0,1,B,D,D,L,n,r,r,r,I
15 ,0,1,0,1,P,A,P,G,r,n,r,r,T
16 ,1,0,1,0,F,O,R,Q,n,n,n,n,N
17 ,0,1,0,1,L,S,S,X,n,n,n,n,I
18 ,1,1,1,0,T,E,E,F,n,r,r,r,I
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19 ,1,0,0,0,G,V,G,D,r,r,r,r,T
20 ,0,0,1,1,A,R,B,P,n,n,r,r,N
21 ,1,1,0,0,C,S,S,T,r,n,n,r,I
22 ,1,0,0,1,O,P,P,V,n,r,r,r,I
23 ,0,1,1,1,D,G,D,R,r,r,r,n,T
24 ,0,1,0,0,Q,B,X,E,r,n,n,r,N
25 ,1,0,1,1,V,L,E,C,n,r,r,r,N
26 ,0,1,1,0,T,D,T,O,r,r,r,n,T
27 ,1,0,0,1,E,F,B,C,n,r,r,n,N
28 ,0,0,0,1,Q,R,D,P,n,n,r,r,N
29 ,1,0,1,0,L,T,T,S,n,r,r,n,I
30 ,1,1,0,0,P,G,P,F,r,r,r,n,T
31 ,0,1,1,1,A,C,D,E,n,r,r,r,N
32 ,0,1,0,0,V,L,L,P,r,n,n,r,I
33 ,1,0,1,1,R,S,R,B,n,n,n,r,T
34 ,0,0,1,0,D,G,G,V,r,r,r,r,I
35 ,0,1,0,1,T,A,F,P,r,n,n,r,N
36 ,1,1,1,0,X,C,X,B,n,r,n,r,T
37 ,0,0,0,0,E,O,E,R,r,n,r,r,T
38 ,1,1,0,1,L,F,V,D,n,n,r,r,N
39 ,0,0,1,1,G,Q,Q,E,r,n,n,r,I
40 ,0,1,1,0,S,B,P,A,n,r,r,n,N
41 ,0,1,1,0,C,T,C,D,r,r,r,r,T
42 ,1,0,0,1,L,X,L,O,n,n,n,n,T
43 ,1,0,1,0,V,R,R,B,r,n,n,r,I
44 ,0,1,1,1,G,C,E,D,r,r,r,r,N
45 ,1,0,0,1,X,P,F,A,n,n,r,n,N
46 ,0,1,1,0,O,Q,O,L,n,n,n,n,T
47 ,0,1,0,0,D,R,S,C,r,n,n,r,N
48 ,1,0,1,1,A,E,E,X,n,r,r,n,I
49 ,0,0,0,1,P,F,F,T,r,n,n,r,I
50 ,1,0,0,0,Q,D,L,A,r,n,n,n,N
51 ,0,1,1,1,B,V,B,O,r,r,r,n,T
52 ,1,1,1,0,F,G,C,D,n,r,r,r,N
53 ,1,0,0,1,P,T,P,E,r,r,r,r,T
54 ,o,1,1,1,R,C,C,Q,n,r,r,n,I
55 ,1,0,0,0,E,B,L,S,r,r,n,n,N
56 ,0,1,1,0,D,S,S,P,r,n,n,r,I
57 ,1,1,1,1,F,A,F,C,n,n,n,r,T
58 ,1,1,0,1,T,Q,T,R,r,n,r,n,T
59 ,1,0,1,0,O,A,A,E,r,n,n,n,I
60 ,0,0,0,1,L,P,L,D,n,r,n,r,T
61 ,0,1,1,0,C,B,S,G,r,r,n,r,N
62 ,1,0,0,1,X,R,X,T,r,n,r,r,T
63 ,1,1,0,1,V,O,R,P,r,n,n,r,N
64 ,0,1,1,0,S,Q,Q,F,n,n,n,n,I
65 ,0,0,1,0,B,L,E,C,r,r,n,r,N
66 ,1,0,0,1,R,G,R,X,n,r,n,n,T
67 ,1,1,1,0,A,T,A,V,n,r,n,r,T
68 ,0,1,0,1,D,C,B,B,r,r,r,r,N
69 ,1,0,1,0,X,P,P,Q,n,r,r,n,I
70 ,1,1,1,0,S,L,S,R,n,n,n,n,T
71 ,0,0,0,1,L,T,A,F,r,r,n,n,N
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72 ,1,1,0,1,O,C,C,E,n,r,r,r,I
73 ,0,1,1,0,P,B,B,V,r,r,r,r,I
74 ,1,0,0,1,R,D,R,G,n,r,n,r,T
75 ,0,0,1,0,T,E,X,S,r,r,n,n,N
76 ,1,1,0,0,C,O,O,F,r,n,n,n,I
77 ,1,0,1,1,Q,S,Q,A,n,n,n,n,T
78 ,0,1,0,0,X,D,P,R,n,r,r,n,N
79 ,0,0,1,1,B,L,L,F,r,n,n,n,I
80 ,1,0,0,0,O,E,E,S,n,r,r,n,I
81 ,1,1,0,1,G,T,G,R,r,r,r,n,T
82 ,0,0,1,0,F,V,V,B,n,r,r,r,I
83 ,1,0,0,1,P,D,P,R,r,r,r,n,T
84 ,0,1,1,0,T,F,E,C,r,n,n,n,N
85 ,1,0,1,1,S,X,Q,A,n,n,r,n,N
86 ,1,1,0,0,V,R,R,L,r,n,n,n,I
87 ,0,1,1,0,F,R,F,O,n,n,n,n,T
88 ,0,0,0,1,B,A,B,L,r,n,r,n,T
89 ,0,1,0,0,L,F,T,C,n,n,r,r,N
90 ,0,0,1,1,A,S,S,R,n,n,n,n,I
91 ,1,1,0,1,D,B,D,X,r,r,r,n,T
92 ,0,0,1,0,E,O,C,T,r,n,r,r,N
93 ,1,1,0,1,S,L,L,F,n,n,n,n,I
94 ,0,1,0,0,B,A,B,D,r,n,r,r,T
95 ,0,0,1,1,Q,X,V,R,n,n,r,n,N
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97 ,1,0,0,0,F,S,F,T,r,n,r,n,T
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104,1,1,0,0,X,A,X,O,n,n,n,n,T
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117,0,0,1,1,T,F,T,E,r,n,r,r,T
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119,1,0,0,0,D,G,G,C,r,r,r,r,I
120,0,1,1,0,O,T,T,E,n,r,r,r,I
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